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BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)

[636]

Competition by roads, waterways, and airways.

(Continuation) ⁽¹⁾.

I. — FRANCE.

The following note received from the French National Railways Company deals with the evolution of the co-ordination policy in France since the end of 1935.

1. — Co-ordination of railway and road transport.

First stage : 1934-1935.

At the beginning of October 1935, the situation was as follows :

The decree of the 19th April, 1934, forbade any new motor transport services to be introduced and instituted a Co-ordination Committee to elaborate agreements between transport undertakings. As a sequence to the findings of this Committee, two decrees dated the 25th February, 1935, and 13th July, 1935, laid down the general clauses for agreements concerning passenger and goods transport. Co-ordination Committees had been formed in each Department, and agree-

ments on public passenger transport were gradually made in a great number of Departments.

Second stage : 1936.

These agreements, however, were much criticised by the General Councils, echoing the fears of the users; consequently the agreements were virtually suspended at the beginning of 1936. A decree dated the 14th November, 1936, ordered the users to be represented on the Departmental Committees and on the Central Co-ordination Committee. The Presidency of the Departmental Committees was confided to the Prefects, that of the Central Co-ordination Committee to the nominee of the Minister of Public Works.

In the meantime, by a circular dated the 12th August, 1936, the Minister asked the Railways to suggest the partial or total suppression of the railway services on certain secondary lines; such proposals from the Railways were, however, rarely carried out.

(1) See *Bulletin*, June 1934 and subsequent issues.

Third stage : 1937.

At the beginning of 1937, the reconstituted and enlarged Co-ordination Committee once more took up the study of the problems raised by the application of the co-ordination measures.

(a) Fiscal measures.

Without waiting for these investigations to be completed, fiscal measures were introduced in July, 1937, to keep the road and railway rates on the same relative level, in spite of the increase in railway rates, found necessary.

In the case of *public transport*, the law of the 8th July, 1937, introduced :

— an annual tax of 500 fr. per ton (tare plus maximum load) on motor vehicles used for the transport of goods; and

— an annual tax of 125 fr. per seat on vehicles used for passenger transport.

Vehicles which are not worked outside the Department to which they belong are exempt from this tax; the taxes are reduced to half in the case of vehicles only used in the Department to which they belong and adjoining Departments.

In the case of *private transport*, a decree of the 16th July, 1937, introduced an annual tax on vehicles used for goods transport; the amount of this tax varies from 1000 fr. in the case of 3-ton lorries to 4000 fr. in the case of 13-ton lorries, with a further increase of 500 fr. for every ton over and above this weight (tare plus maximum load). This tax only applies to vehicles which are used outside the Department to which they belong and the adjoining Departments.

Finally, the law of the 8th July, 1937, increased the tax on certain fuels (gas oils, lower grades of petrol and benzol).

(b) Co-ordination measures.

1. A law of the 31st August, 1937, defined and explained the new ideas on which the French co-ordination policy is based.

A Higher Transport Council was set up under the Minister of Public Works to study the transport question as a whole; together with the former Higher Railway Council, all the former Central Co-ordination Committees (railway and road transport; railway and water; railway, air, and sea; Higher Co-ordination Committee) are all included in this Council.

In the case of *public passenger transport*, the General Departmental Councils are now required to draw up the Departmental co-ordination plans for passenger transport in collaboration with the Technical Committees.

These plans are put into force by an order of the Minister of Public Works; the road services provided for in these plans are operated subject to the conditions of an authorisation from the Minister, and specifications the type of which is laid down by decree.

The Railway may be authorised by the Minister to subsidise those road services replacing a railway service, which cannot meet their operating costs.

Road passenger services which uselessly and expensively duplicate railway services must be suppressed, in principle by making exchanges of licences. The buying up of such services is permissible in exceptional cases.

In the case of *public goods transport*, great liberty is allowed to short-distance transport which as a rule does not seriously compete against the railway.

To prevent a tariff war between the various methods of long-distance transport, the road firms authorised to work such transport are encouraged to join the

Unions which must be approved by the Minister and, under the control of the State and the Co-ordination Committees, will make rating agreements with the railway, which will bind all their members.

Transport undertakings belonging to these Unions are granted exemption from some taxes, whilst the others are severely taxed in order to make competition very difficult.

The railway may be authorised by the Minister of Public Works to buy up the stock and plant of certain road services duplicating the railway services.

Investigations upon this new basis are now being actively carried out by the Railway and Road Co-ordination Committee, and it would appear that the era of actual realisation is at last in sight.

2. A decree of the 25th February, 1938, published in the *Journal Officiel* of the 1st March, 1938, has defined how the decree of the 31st August, 1937, is to be applied in the case of passenger transport.

This decree, which replaces and abolishes those of the 25th February, 1935, and 14th November, 1936, lays down the composition of the Departmental Technical Committees, and reproduces, moreover, the clauses of the decree of the 14th November, 1936.

It determines the conditions under which the Departmental co-ordination plans are to be elaborated, and the procedure for their examination and approbation.

It gives the special conditions under which road services can be maintained parallel to the railway; in particular the rates of the former must be at least equal to those of the railway in the case of common routes.

It lays down that the licences required

by the decree of the 31st August, 1937, will be valid until the 31st December, 1947, and that the Higher Transport Council must lay before the Minister of Public Works before the 1st January, 1947, its proposals for the renewal or modification of licences on the 1st January, 1948.

2. — Realisation of the co-ordination of rail and water transport.

The decree of the 15th May, 1934, which laid down the basis for co-ordination between rail and water transport was ratified by a law of the 30th March, 1936.

Amongst other things, the decree of the 31st August, 1937 mentioned above :

— has brought the Central Co-ordination Committee for rail and water transport into the Higher Transport Council;

— has provided for special measures the effect of which would be to divide up the traffic more fairly between the small boats and other water transport undertakings, and for regulation of the freights.

A fairly large number of agreements about the apportionment of the traffic between rail and water services were made by the Regional Co-ordination Committees, approved by the Central Committee, and sanctioned by decree of the Minister of Public Works. These were either regional agreements, applying to all the traffic, like that made between the *P. O.-Midi Railways* and water transport undertakings on the Midi and Garonne canals, or special agreements covering certain traffic or routes. Other agreements are now being drawn up, especially in the case of the boat services on the Lower Seine.

In addition, the collaboration obtained in the Regional Committee between rail

and water representatives has made it possible to avoid having to introduce competitive rates and thereby suffer receipt losses.

It may therefore be said that at the present time co-ordination between rail and water transport has become a concrete fact in France.

3. — Rail, air and sea co-ordination.

The law of the 30th October, 1935, set up a Committee to investigate the possibility of making agreements to co-ordinate transport :

- by rail and air,
- by rail and sea;
- by sea and air.

This Committee includes experts nominated respectively by the former Executive Committee of the French main-line Railways, the Central Committees of the French coastal and overseas navigation services, and the airway Companies.

This Committee has now become part of the new Transport Council.

The first concrete result of the decree of the 30th October, 1935, was obtained in December, 1935, when the representatives of the main-line Railways and the Central Committee of French Shipowners made an agreement to abstain from taking any rating or other measures likely to change the distribution of traffic between rail and water transport until such time as co-ordination was achieved.

This truce continues.

* * *

II. — ALGERIA.

Algerian Railways.

The information given below is taken

from a note received from the Joint Management of the Algerian State Railways and the Algerian lines of the *Paris-Lyon-Méditerranée Railways* (1st and 2nd quarters of 1937).

Passengers.

During the year 1937 (2nd quarter), it was decided to increase the passenger rates owing to the increased costs due to the application of the new social laws. The increase was about 30 % in the case of reduced fares and 40 % on the general fares. The Co-ordination Committee made the road firms increase their rates by 30 % as from the same date.

Goods.

Agreement has been considered and obtained on the basis of a reduction of the tonnage carried by road firms owning more than one vehicle, and an increase in the competitive railway rates.

The slow goods rates introduced to fight road competition have been revised. The proposals include readjustments and increases in rates in most cases; these modifications have become necessary owing to an agreement which provides for a reduction of 25 % of the tonnage of road firms and the application of a minimum rate.

The co-ordination of goods transport has consequently entered upon its final stage.

* * *

BRITISH INDIA.

We are informed by the Bombay, Baroda and Central India Railway Company that the following important develop-

ments have been effected since February 1937 :

(1) The United Provinces Government have constituted a Board of Traffic and Communications. The functions of this Board are :

(a) To co-ordinate the activities and the policy of all Licensing Authorities appointed under the Motor Vehicles Rules, framed under the Motor Vehicles Act, and to advise the Local Government generally on matters pertaining to the development and regulation of road traffic.

(b) To adjust points of difference between road and rail interests and to im-

plement as far as possible the policy framed by the Transport Advisory Council.

(2) The Agent to the Governor General in Rajputana, has amended Article 6 of part III of the Rajputana (Railway Lands) Motor Vehicles Rules, 1932, by which a permit, allowing a person to bring into railway lands any Public vehicle for the purpose of plying for hire or for the purpose of taking up or setting down passengers, will now be issued only after due consultation with the District Traffic Superintendent of the Railway concerned.

Laying turnouts in curves,

by J. DUBUS,

Permanent Way Engineer, Belgian National Railways Company.

Introductory.

The laying of turnouts into curved track has been the subject of numerous articles in the technical press.

The « Handbuch der Ingenieurwissenschaften », Part 5, Vol. 3, 1923, deals with the completely general case. Therein the « rails » method is employed, each track being represented by the two lines of rails composing it, although in Germany the « one line per track, or centre-line » method of representation has long been in current use for layout drawings.

As is well known, in this method, at present adopted by the majority of Systems, turnouts are represented by a triangle the vertices of which coincide with mathematically determined points. The object of the present study is to deal by the latter method with the question of the introduction of turnouts into curves.

By employing the centre-line method we have been able to bring to light a number of interesting facts and to formulate the laws controlling the various characteristic factors involved.

We conclude our study with a brief analysis of the method of dealing with turnouts in curves, adopted by the Belgian National Railways Company.

CHAPTER I.

The « rails » method.

We summarise briefly the general so-

lution of the problem as given in the « Handbuch » mentioned above, retaining the German notations.

The gauge of the through road is denoted by s , and that of the branching-off road through the points and crossing by s' , and referring to figure 1 :

$BC_1 = e$, the width of the head of the rail plus the flangeway at the heel of the blade;

ω , = the angle between the stock-rail and the tangent, at the heel, to the closed switch tongue;

α , = the crossing angle;

δ , = the angle subtended by the arc of the turnout curve at its centre;

$\varphi = \delta - (\alpha - \omega)$, the angle subtended by the arc of the through road curve at its centre in the case illustrated — the case of deflecting devices curved in the same direction;

r'_o = mean radius of the through road curve;

r_o = mean radius of the turnout road

$FK = g$; $GK = g_1$, the straight portions of the crossing.

We assume, moreover, to make the case quite general, that the connecting curves in question are not tangential at the heel of the blade, whence the straight portions : $BD = v_1$ and $C_1E = v_2$.

CHAPTER II.

The "centre line" method.

We will call the existing track, into which a connection is to be introduced, the « through » or « main line » road, and the other track the « turnout » road, or « branch line ».

In considering the connecting curves required between the points and the crossing we will start with the assumption that the geometrical tangents of the through road are unequal, while those of the turnout road are equal.

This assumption is sufficiently general to cover the majority of cases in practice, as failing to make full use of the tangents on the turnout road is not very de-

sirable, especially in a turnout with curves in the same direction.

Explanation of figure 2 :

Let : $N_a T_{a1} T_{a2}$, be the triangle representing the turnout, with an angle of deviation α , assumed fixed ;

$N_c T_{c1} T_{c2}$, be the triangle representing the crossing of angle β , (assumed for the sake of this investigation to be capable of movement) ;

T_{a1} and T_{a2} , T_{c1} and T_{c2} , be the tangential points of the two connecting curves with the centre line of the switch and crossing respectively ;

$T_{a1} S_e = T_{c1} S_e$, be the geometrical tangents of the connecting curve of the through road, making an angle γ with one another ;

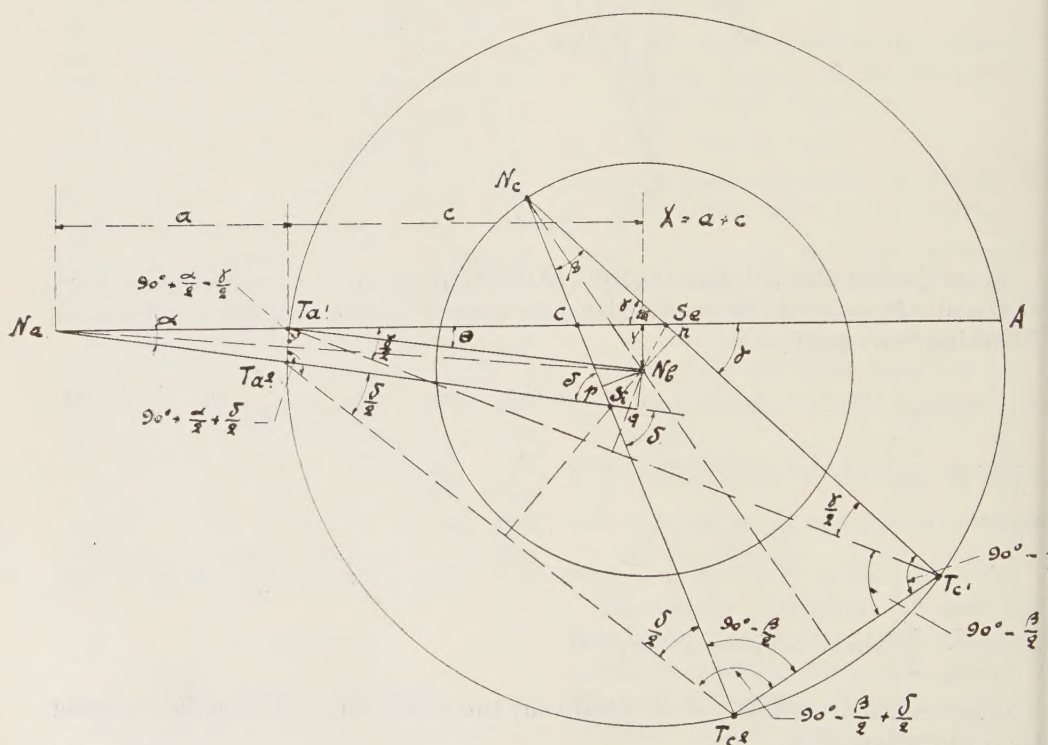


Fig. 2.

$T_{a^2} S_i = T_{c^2} S_i$, be the tangents of the connecting curve of the turnout road, making an angle δ with one another.

We know that : $\delta = (\beta - \alpha) \pm \gamma$, from the triangles $N_a C S_i$ and $N_c C S_e$ of figure 2 (+ γ for deflecting devices with

curves in the same direction, — γ for devices with curves in opposite directions).

We will call the radii of the connecting curves of the through and turnout roads, R and r respectively, and that of the turnout road in the case of a straight main line, R_1 .

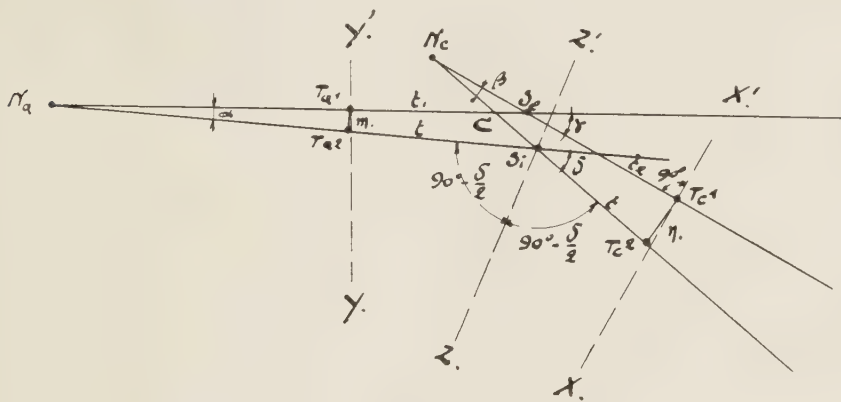


Fig. 3.

We now project the polygon $T_{a^1} S_e T_{c^1} T_{c^2} S_i T_{a^2}$ on to the axes XX' and YY' perpendicular to $T_{c^1} S_e$ and $T_{a^1} S_e$ respectively.

Putting, for brevity :

$$T_{a^1} T_{a^2} = m = 2 a \sin \frac{\alpha}{2} \quad \text{and} \quad T_{c^1} T_{c^2} = n = 2 b \sin \frac{\beta}{2};$$

we get :

$$1) \quad t_1 = \frac{n \cdot \cos \frac{\beta}{2} - m \cdot \cos \left(\frac{\alpha}{2} - \gamma \right) - t [\sin \beta + \sin (\beta - \delta)]}{\sin \gamma}.$$

$$2) \quad t_2 = \frac{m \cdot \cos \frac{\alpha}{2} - n \cdot \cos \left(\gamma + \frac{\beta}{2} \right) + t [\sin \alpha + \sin (\alpha + \delta)]}{\sin \gamma}.$$

On the other hand,

$$t = r \times \tan \frac{\delta}{2}.$$

fixed for r , 150 m. ($7 \frac{1}{2}$ chains), for

instance, whence : $t = 150 \times \tan \frac{\delta}{2}$,

In the case of turnouts introduced into curves of small radius, a minimum is

δ being related to the other angles by the equation : $\delta = \beta - \alpha \pm \gamma$.

Equation (4) becomes :

$$T = \frac{b \cdot \sin \frac{\beta}{2} \cdot \cos \frac{\alpha}{2} - a \cdot \sin \frac{\alpha}{2} \cdot \cos \frac{\beta}{2}}{\sin \frac{\alpha + \beta}{2}} \quad (5)$$

a , b , α and β being constants for a given type of turnout, $T_{a1} S_e = S_e T_{c1} = \text{constant } c$.

It can be readily shown that :

$$a + T = \frac{(a + b) \tan \frac{\beta}{2}}{\tan \frac{\alpha}{2} + \tan \frac{\beta}{2}} = X,$$

$$S_e N'_b = (a + T) \tan \frac{\alpha}{2} = \frac{a + b}{\cot \frac{\alpha}{2} + \cot \frac{\beta}{2}} = S_e N_b = Y,$$

which is the ordinate of the node N_b of the turnout, and is constant for a given type of deflecting device.

The points N_b and N'_b coincide, and the node N_b of the junction is fixed.

The bisector of the angle $T_{a2} S_i T_{c2}$ likewise passes through N_b ; for proof it is sufficient to drop perpendiculars from N_b on $T_{a2} S_i$ and $T_{c2} S_i$; these must be equal to one another since they are both equal to the same third side $N_b S_e$ (fig. 4).

If we now let the schematic triangle representing the crossing rotate about N_b , the bisector of the angle $T_{a1} S_e T_{c1}$ also passes through the point N_b (see fig. 2).

In fact : $N_b n = N_b p = (b - T) \tan \frac{\beta}{2} = (a + T) \tan \frac{\alpha}{2} = N_b q = N_b m = \text{constant } Y$, above.

The circle of centre N_b and constant radius Y , is the envelope of the tangents to the connecting curves of the through and turnout roads. This is easily checked by the envelopes theory.

which is the abscissa of the node N_b of the turnout, and is constant for a given type of deflecting device.

Let us erect $S_e N_b$, perpendicular to $T_{a1} T_{c1}$ at its mid-point S_e , and let it cut $N_c N_b$, the bisector of angle β , at N'_b .

$$S_e N_b = (b - T) \tan \frac{\beta}{2} = \frac{a + b}{\cot \frac{\alpha}{2} + \cot \frac{\beta}{2}}$$

substituting for T its value obtained from equation (5).

Let N'_b be the intersection point of the perpendicular $S_e N_b$ with the bisector $N_a N'_b$; then :

The quadrilateral $T_{a1} T_{c1} T_{c2} T_{a2}$ is inscribable, the radius of the circumscribed circle being :

$$\rho = \sqrt{c^2 + Y^2} = \text{constant}.$$

The point N_c also moves on the circumference of a circle of constant radius equal

$$\text{to : } \frac{Y}{\sin \frac{\beta}{2}}$$

Summarising, we may conclude that :

« The bisectors of the angles at the vertices of the isocles schematic triangles representing the points (straight, shaped or flexible tongues) and crossing, and of the central angles of the connecting curves, intersect at a fixed point, independently of the radius of the track into which the turnout is introduced. »

Our colleague, M. LAMY, makes many interesting applications of this fact in his course of surveying at the University of Charleroi.

MARIDET, in his classic work on per-

manent-way calculations (1876), shows that, approximately :

$$\frac{1}{r} = \frac{1}{R_1} \pm \frac{1}{R} \text{ or } r = \frac{R \cdot R_1}{R \pm R_1}.$$

It is as well to recall that R_1 is the radius of the turnout curve in the case of a straight main line.

The curvature of the turnout road is

$$\tan \frac{\delta}{2} = \tan \left(\frac{\beta - \alpha}{2} \pm \frac{\gamma}{2} \right) = \frac{\tan \frac{\beta - \alpha}{2} \pm \tan \frac{\gamma}{2}}{1 \mp \tan \frac{\beta - \alpha}{2} \cdot \tan \frac{\gamma}{2}}$$

$$\tan \frac{\beta - \alpha}{2} = \frac{c}{R_1 + Y}.$$

$$\tan \frac{\gamma}{2} = \frac{c}{R \mp Y}.$$

$$\tan \frac{\delta}{2} = \frac{c}{r \mp Y}.$$

equal to that of a straight main line, assumed to be increased or diminished by the curvature of the curved through road, according as the two curves are in the same or opposite directions (of similar or contrary flexure).

This result follows from the equations hereafter.

We have :

Where there is a double sign, the upper one refers to the case of deflecting devices with curves of similar flexure, and the lower one to those of contrary flexure.

Taking into account the fact that $\rho^2 = c^2 + Y^2$, and putting : $2 R_1 Y + \rho^2 = F$,

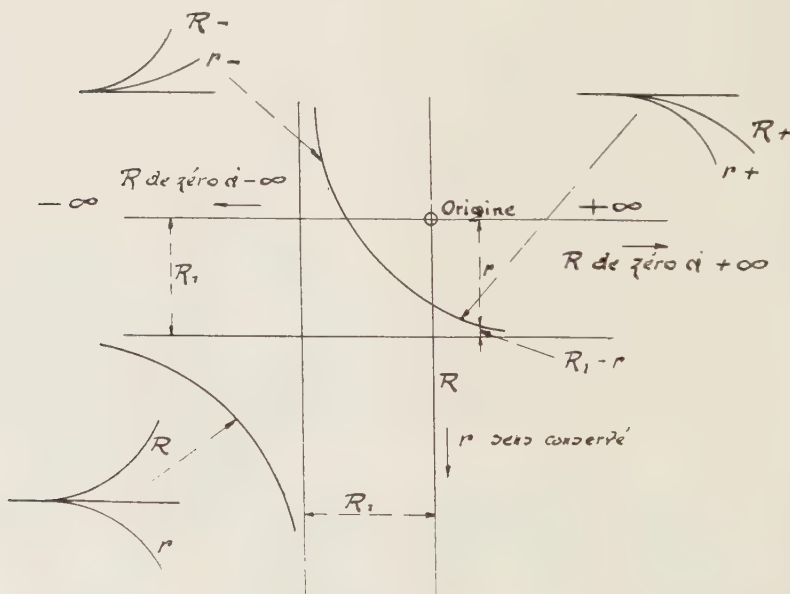


Fig. 5.

(a fixed quantity for a given combination of points and crossing), we get :

$$r = \frac{R \cdot R_1 - F}{R + R_1} \quad (1) \text{ Turnouts with curves of similar flexure.}$$

and

$$r = \frac{R \cdot R_1 + F}{R - R_1} \quad (2) \text{ Turnouts with curves of contrary flexure.}$$

If F is neglected, MARIDET's result is obtained.

(1) and (2) may also be written :

$$\begin{cases} (R_1 - r)(R + R_1) = R_1^2 + F & \text{equilateral} \\ (r - R_1)(R - R_1) = R_1^2 + F & \text{hyperbolæ.} \end{cases}$$

Differentiating with respect to R and r , we find the co-ordinates of the centre :

$$\begin{cases} r = R_1 \text{ and } R = -R_1 & \left\{ \begin{array}{l} \text{Turnouts with curves} \\ \text{of similar flexure.} \end{array} \right. \\ r = R_1 \text{ and } R = R_1 & \left\{ \begin{array}{l} \text{Turnouts with curves} \\ \text{of contrary flexure.} \end{array} \right. \end{cases}$$

By taking logarithms of the two sides, this hyperbolic relationship is converted into a linear one :

$$\begin{aligned} \log(R_1 - r) + \log(R + R_1) &= \log(R_1^2 + F) \\ \log(r - R_1) + \log(R - R_1) &= \log(R_1^2 + F) \end{aligned}$$

equations of the form : $y + x = \text{constant}$, i. e. straight lines inclined 45° to the axes.

For a given combination of points and crossings, therefore, the curve expressing the relationship between r and R is an equilateral hyperbola.

Law governing the variation in length of the connecting curve of the through road, in terms of the angle γ .

Call the variable angle γ , x .

Convert the properties of the diagram to polar co-ordinates, the pole being T_{a1} and the initial line, the chord $T_{a1} A$.

The constant angle Θ which the radius $T_{a1} N_b$ makes with the chord $2c$ of the circular geometrical locus of the tangent points of the intermediate arcs, is very small for the various combinations of points and crossings.

We have :

$$\text{Arc } T_{a1} T_{c1} = s = R \cdot x = - \frac{x \cdot \rho \cos\left(\frac{x}{2} - \Theta\right)}{\sin \frac{1}{2} x}.$$

As a matter of fact :

$$R \cdot \sin \frac{1}{2} x = \rho \cos \left(\frac{x}{2} - \Theta \right).$$

We will now investigate the function $s = f(x)$.

$$\text{When } x = 0, \text{ we observe that } \lim_{x \rightarrow 0} \frac{\frac{x}{2}}{\sin \frac{1}{2} x} = 1.$$

$s_0 = 2 \rho \cos \Theta$, that is $2c$ (the case of the straight main line).

$$\text{When } x = 2 \Theta, s_{2\Theta} = \frac{\Theta}{\sin \Theta} \cdot 2 \rho > s_0, \text{ because } \frac{\Theta}{\sin \Theta} > \cos \Theta.$$

The function is therefore increasing; it passes through a maximum.

Differentiating and equating to zero :

$$\frac{ds}{dx} = \frac{\rho}{2 \sin^2 \frac{1}{2} x} \left[2 \sin \frac{1}{2} x \cos \left(\frac{x}{2} - \Theta \right) - x \cos \Theta \right] = 0.$$

Since $\sin^2 \frac{1}{2} x \neq 0$, the condition for a maximum is :

$$2 \sin \frac{1}{2} x \cos \left(\frac{x}{2} - \Theta \right) = x \cos \Theta.$$

This maximum is furthermore attained for a very small value of x ; we may in fact write, as a good approximation, Θ being negligible,

$$2 \sin \frac{1}{2} x \cdot \cos \frac{1}{2} x = \sin x \approx x$$

which is only exactly true when $x = 0$.

If x becomes negative (turnouts with curves of contrary flexure), s rapidly diminishes, since :

$$s = \frac{(-x) \rho \cos \left[-\left(\frac{1}{2} x + \Theta \right) \right]}{\sin \left(-\frac{1}{2} x \right)}.$$

As to the lengths of the tangents and the laws governing their variation, they can be established at once.

$$\text{Length } t, \text{ of a tangent} = \frac{\rho \cos \left(\frac{x}{2} - \Theta \right)}{\cos \frac{x}{2}}$$

$$t = \rho \left(\cos \Theta + \sin \Theta \operatorname{tg} \frac{x}{2} \right)$$

which is a straight line law of the form

$$y = mx + b.$$

The lengths of the tangents therefore increase, in the case of curves in the same directions, x positive, and decrease

in the case of curves of opposite flexure, x negative.

General case. — Every movement of a figure in the plane consists of a rotation followed by a translation; the general case can therefore be studied by impressing upon the schematic triangle representing the crossing the two fundamental movements mentioned.

The rotation of the triangle about the fixed point N_b (see figure 2 above), the node of the turnout, has enabled us to investigate the possibilities of equal tangents.

Some interesting solutions can be obtained by departing from the principle of making full use of the tangents, and moderately increasing the length of the deflecting device. This case can be dealt with by impressing upon the triangle supplementary translation.

The diagram has been distorted slightly for the sake of clearness; the geometrical tangent $T_{a1} S_e$ is denoted by T , and the tangent $T_{a2} S_i$ by t .

Let us imagine that the application of the previous method has given a radius r less than 150 m. ($7 \frac{1}{2}$ chains) regarded as the minimum.

Keep the same value for δ , and determine the small increment Δt of the tangent t , giving $r = 150$ m.; then :

$$\frac{t + \Delta t}{\tan \frac{\delta}{2}} = r = 150 \text{ m.}$$

Set off $S_i H = S_i K = \Delta t$; draw H .

perpendicular to the axis XX , the bisector of the angle $T_{a2} S_i T_{c2}$, equal to $180^\circ - \delta$.

We now impress upon the schematic triangle representing the crossing, a movement of translation $2 \times \Delta t \cdot \cos \frac{\delta}{2}$ in the

direction HK , such that the point H moves to the point K , and the point N_c to N'_c .

The geometrical tangents to the turnout curve $T_{a2} K$, $T'_{c2} K$ will now be equal to $\pm \Delta t$, and will enable a radius r equal to 150 m. to be obtained.

We will now see how the tangents T_{a1} , $T_{c1} S_e$ of the trough road have varied.

$T_{a1} S_e$ will have been shortened by the amount $S_e S'_e$, and $T_{c1} S_e$ lengthened by $P + QS_e$.

Determine these amounts :

In the right-angled triangle $N_c P N'_c$, we have :

$$PN'_c = 2 \Delta t \cdot \cos \frac{\delta}{2} \sin \left(\beta - \frac{\delta}{2} \right)$$

$$N_c P = 2 \Delta t \cdot \cos \frac{\delta}{2} \cos \left(\beta - \frac{\delta}{2} \right).$$

The right-angled triangle $QS_e S'_e$ gives :

$$S'_e S_e = \frac{QS'_e \text{ or } PN'_c}{\sin \gamma}$$

$$QS_e = \frac{QS'_e \text{ or } PN'_c}{\tan \gamma}.$$

There still remains to verify whether the radius R is suitable.

$$R = \frac{T_{a1} S_e - S'_e S_e}{\tan \frac{\gamma}{2}}.$$

Laws governing the variation of R and r .

We first determine the parameters of R and r in terms of Δt . Denote the radii obtained when making full use of the tangents, by R_T and r_t .

$$R = R_T - \frac{\cos \frac{\delta}{2} \sin \left(\beta - \frac{\delta}{2} \right)}{\sin^2 \frac{\gamma}{2}} \cdot \Delta t.$$

$$r = r_t + \frac{1}{\tan \frac{\delta}{2}} \cdot \Delta t.$$

In the case of a simple movement of translation :

$$\frac{\cos \frac{\delta}{2} \cdot \sin \left(\beta - \frac{\delta}{2} \right)}{\sin^2 \frac{\gamma}{2}} = \text{constant } K.$$

$$\frac{1}{\tan \frac{\delta}{2}} = \text{constant } k.$$

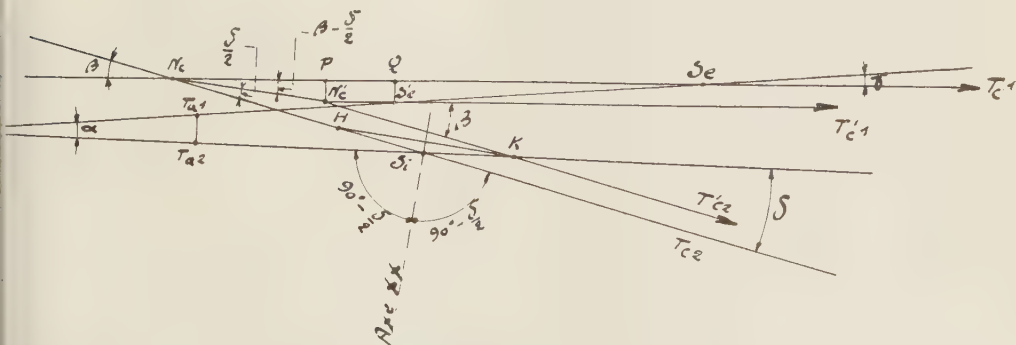


Fig. 6.

Whence the two parametric equations :

$$\begin{aligned} R &= R_T - K \Delta t \\ r &= r_t + k \Delta t \end{aligned} \quad \text{for } \Delta t = 0, R = R_T \text{ and } r = r_t.$$

Eliminating Δt :

$$R = R_T - \frac{K}{k} (r - r_t).$$

$$\frac{K}{k} = \frac{\sin \frac{\hat{\delta}}{2} \cdot \sin \left(\beta - \frac{\hat{\delta}}{2} \right)}{\sin^2 \frac{\hat{\gamma}}{2}} = \text{constant } m.$$

$$R_T + \frac{K}{k} r_t = \text{constant } q.$$

Whence : $R = -mr + q$, which is a straight line law. As a particular case :

$$R = r = \frac{q}{1 + m}.$$

Remarks.

1. — The extent of the translation imparted to the schematic triangle of the crossing furnishes an easy way of calculating the increase in the length of the turnout.

2. — If the unused portion of the geometrical tangent becomes appreciable, it may prove interesting to replace this alignment by a compound curve having, for example, two radii ρ_1 and ρ_2 such that $\rho_1 -$

ρ_2 or $\frac{1}{\rho_2} - \frac{1}{\rho_1}$ is a minimum, provided ρ_1 and ρ_2 have acceptable values.

3. — For a particular value of δ , the extent of the translation to be imparted to the schematic triangle of the crossing in order to make $R = r$ is given by :

$$A = 2 \cdot \frac{R_T - r_t}{K + k} \cdot \cos \frac{\hat{\delta}}{2}.$$

Example. — The application of the method of equal tangents to a Belgian National Railways F⁴H² turnout with flexible tongues and $R = 200$ metres gives $r = 131$ metres, with

$$\begin{aligned} \gamma &= 4^\circ 6' 15'', & \delta &= 6^\circ 14' 30'' \text{ m.} \\ \beta &= 5^\circ 1' 24'', & t &= 7.14 \text{ m.} & T &= 7.17 \text{ m.} \end{aligned}$$

To make :

$$r = 150 \text{ metres,}$$

$$t + \Delta t = 7.14 \times \frac{150}{131} = 8.20 \text{ m.,}$$

whence,

$$\Delta t = 1.06 \text{ metres.}$$

The extent of the translation to be imparted to the schematic triangle of the crossing is :

$$2 \Delta t \cos \frac{\hat{\delta}}{2} = 2 \cdot 1.06 \times \cos 3^\circ 7' 15'' \approx 2.12 \text{ metres;}$$

$$PN_c = 2 \Delta t \cdot \cos \frac{\hat{\delta}}{2} \sin \left(\beta - \frac{\hat{\delta}}{2} \right) = 2.12 \times \sin (5^\circ 1' 24'' - 3^\circ 7' 15'') = 0.07 \text{ metre;}$$

$$N_c P = 2 \Delta t \cdot \cos \frac{\hat{\delta}}{2} \cos \left(\beta - \frac{\hat{\delta}}{2} \right) = 2.12 \times \cos (5^\circ 1' 24'' - 3^\circ 7' 15'') = 2.12 \text{ metre}$$

$$S'_e S_e = \frac{0.07}{\sin 4^{\circ}6'15''} = 0.98 \text{ metre};$$

$$QS_e = \frac{0.07}{\tan 4^{\circ}6'15''} = 0.975 \text{ metre.}$$

The radius R therefore becomes :

$$R = \frac{7.17 - 0.98}{\tan \frac{\gamma}{2} \text{ or } 0.03584} = 173 \text{ metres.}$$

The tangent $T_{a1} S_e$ is therefore altered from 7.17 metres to 6.19 metres, and the tangent $T_{c1} S_e$ from 7.17 metres to $7.17 + 0.975 + 2.12 = 10.27$ metres of which only 6.19 metres is made use of.

Law connecting R and r .

$$R = -mr + q.$$

m and q can be obtained directly, as follows :

We note that when $\Delta t = 0$, then $R = 200$ metres and $r = 131$ metres, giving the first point of the straight line law.

When $\Delta t = 1.06$ metres, then $R = 173$ metres, and $r = 150$ metres, which determines a second point.

Then :

$$-m = \frac{173 - 200}{150 - 131} = -1.40.$$

$$R = -1.4r + q,$$

Putting $R = 200$ and $r = 131$, we get :

$$q = 383 \text{ and } R = -1.4r + 383.$$

Putting $R = r$,

we get :

$$R = r = 160 \text{ metres,}$$

corresponding to an increment $\Delta t = 1.60$ metres and to a translatory movement of approximately 3.20 metres in extent.

The case of a through road curve with equal tangents.

Translatory movement.

Extent A of the translatory movement :

$$2 \Delta T \cdot \cos \frac{\delta}{2}.$$

$$N_c P = 2 \Delta T \cdot \cos \frac{\gamma}{2} \sin \left(\beta + \frac{\gamma}{2} \right).$$

$$N_c P = 2 \Delta T \cdot \cos \frac{\gamma}{2} \cdot \cos \left(\beta + \frac{\gamma}{2} \right).$$

$$S_i S'_i = S'_i Q \times \frac{1}{\sin \delta}.$$

$$S_i Q = S'_i Q \times \cot \delta.$$

Variation of $S_i T_{c2} = N_c P - S_i Q$.

$$R = R_T + K \cdot \Delta T; K = \frac{1}{\tan \frac{\gamma}{2}}.$$

$$r - r_i = k \Delta T$$

$$k = \frac{\cos \frac{\gamma}{2} \sin \left(\alpha - \frac{\gamma}{2} \right)}{\sin^2 \frac{\delta}{2}}.$$

Eliminating Δt :

$$R = R_T + \frac{K}{k} (r_i - r)$$

$$\frac{K}{k} = \frac{\sin^2 \frac{\delta}{2}}{\sin \frac{\gamma}{2} \cdot \sin \left(\alpha - \frac{\gamma}{2} \right)} = m.$$

Putting :

$$R_T + \frac{K}{k} r_i = q$$

we get :

$$R = -mr + q$$

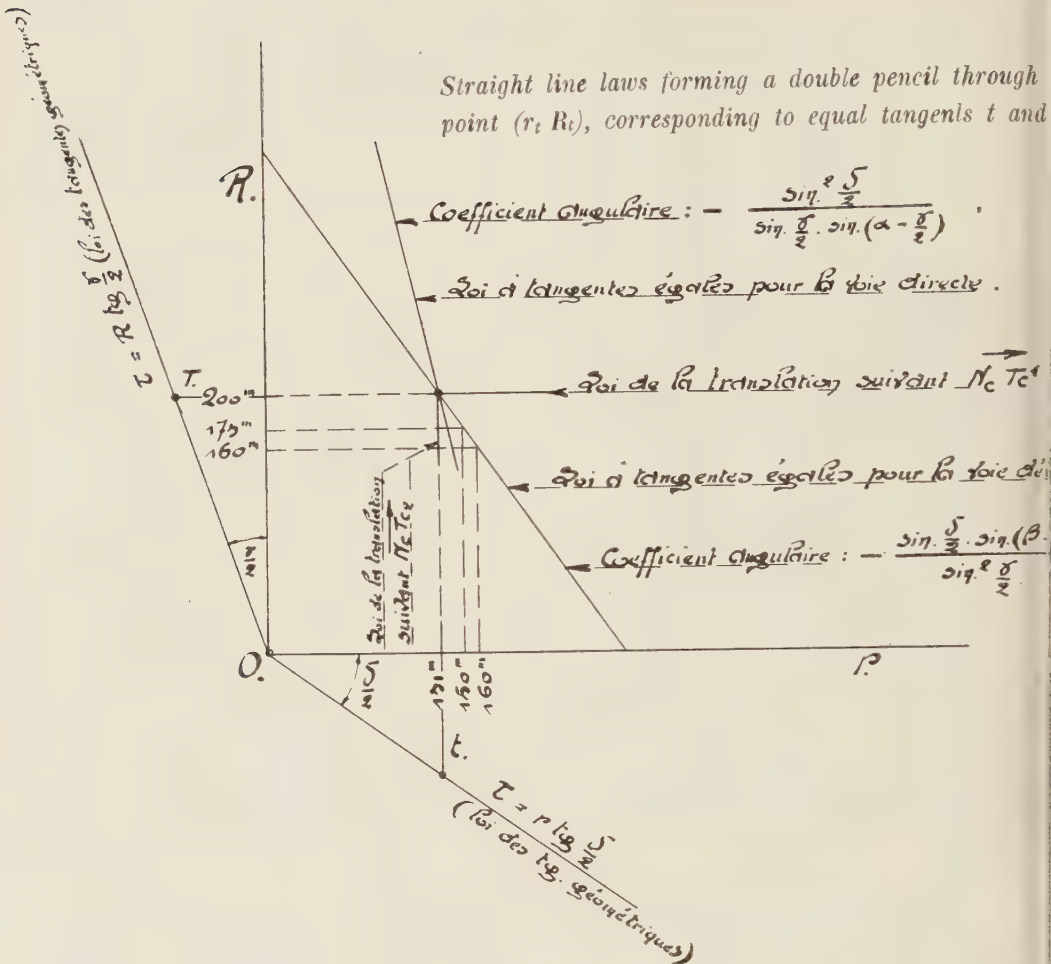


Fig. 7.

Explanation of French terms :

Coefficient angulaire = gradient. — Loi à tangentes égales pour la voie directe = Equal tangents line for the through road curve. — Loi à tangentes égales pour la voie déviée = Equal tangents line for the branch curve. — Loi de la translation suivant ... = Translatory movement along ... — Loi des tangentes géométriques = Geometrical tangents line.

which is a straight line passing through the point (r_i , R_T).

The general case regarded from the standpoint of pure mathematics.

To the two particular translatory move-

ments considered above we can add others in the directions $\overline{N_c T_{c1}}$ $\overline{N_c T_{c2}}$.

In the case of direction $\overline{N_c T_{c1}}$, R remains constant and equal to R_T ; in the

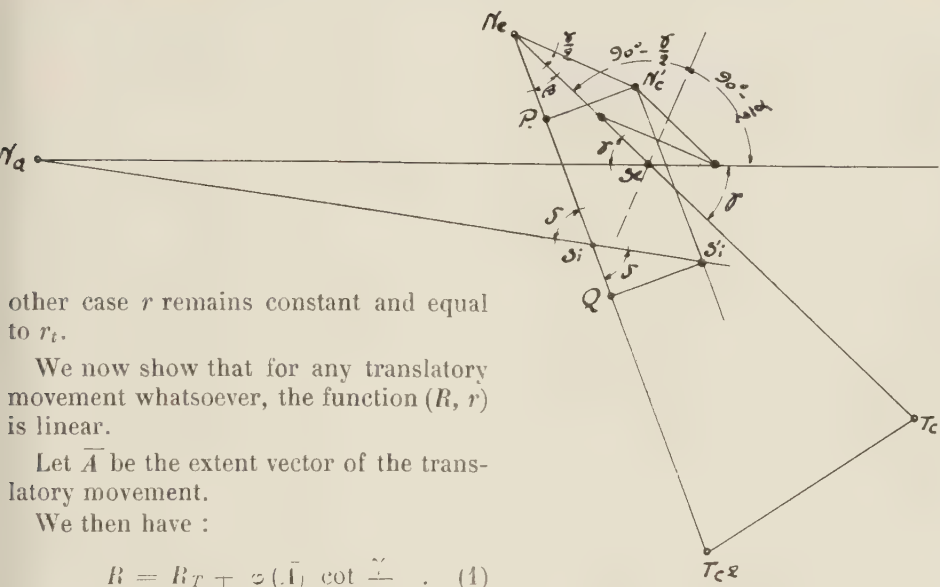


Fig. 8.

other case r remains constant and equal to r_t .

We now show that for any translatory movement whatsoever, the function (R, r) is linear.

Let \bar{A} be the extent vector of the translatory movement.

We then have :

$$R = R_T + \varphi(\bar{A}) \cot \frac{\gamma}{2} \quad (1)$$

$$r = r_t + \psi(\bar{A}) \cot \frac{\delta}{2} \quad (2)$$

$\varphi(\bar{A})$ and $\psi(\bar{A})$ are functions independent of R and r , and vanish when $A = 0$.

Multiply (1) by the arbitrary factor λ (not equal to zero) which can be determi-

ned from the equation $\lambda \varphi(\bar{A}) \cot \frac{\gamma}{2} = \psi$

$(\bar{A}) \cot \frac{\delta}{2}$, it being assumed that $\tan \frac{\gamma}{2}$

is other than zero, λ is thus independent of R and r , and we have :

$$\left. \begin{aligned} \lambda R &= \lambda R_T + \lambda \varphi(\bar{A}) \cot \frac{\gamma}{2} \\ r &= r_t + \psi(\bar{A}) \cot \frac{\delta}{2} \end{aligned} \right\} \text{whence } R = R_T - \frac{1}{\lambda} (r_t - r),$$

which is a straight line passing through the point : $R = R_T$
 $r = r_t$.

Conclusion.

The problem of introducing turnouts into curved track is therefore capable of a *completely general solution* by means of two sets of an infinite number of co-ordinate values of (R, r) .

Each point on the equilateral hyperbola representing pure rotation of the

schematic triangle of the crossing, is also the intersection of an infinite number of straight lines disposed in the form of a double pencil, the common vertex of which has the same co-ordinates as the point in question on the hyperbola; but the hyperbola itself is the simple summation of an infinitely large number of such points.

CHAPTER III.

Method of introducing turnouts into curved track, adopted by the Belgian National Railways Company.

Owing to the existence of the straight portions of points and crossings, the strict application of the principles developed above generally necessitates an appreciable reduction in the original radius of the through road curve.

As is known, a turnout can be laid :

1. tangent to the original curve at the blade point;
2. tangent to the original curve at the crossing;
3. tangent to the original curve at the heel of the blade.

In all cases the original curve of the through road must be modified slightly, and thrown out towards the outside of the formation, either within the limits of the intermediate rails between the points and the crossing, or clear of these devices.

As is known, this is a serious obstacle to the rapid preparation of draft plans for station layouts, comprising numerous combinations of apparatus : turnouts, slip points, diamonds, etc.

This question has been made the subject of a very comprehensive and searching investigation on the part of our colleague of the Belgian National Railways, Mr. JACOBS, Engineer, the results of which have been issued in the form of instructions to the permanent-way staff.

The following are the basic principles of M. JACOBS' method :

1. The existing curvature of the

through road is maintained, both within and beyond all blocks of points and crossings, and the latter are laid in the curve *as chords*.

2. Every combination of points and crossings has its own constant lead, depending on the type of deflecting apparatus used, and is determined once and for all. This principle of a constant and characteristic lead enables a block of points and crossings to be inserted on the draft plan of a new scheme, in one or another existing curved road, by means of a few simple and rapid calculations.

This method has the considerable practical advantage of not altering in any way the general alignment of the original curves. At the same time, however, the introduction of, say, a turnout along the chord of the through road, results in two local irregularities, namely :

1. A discontinuity of the curve equivalent to a rotation of the tangent at the blade point;
2. A lateral displacement of the rail within the length of simple devices, turnout and crossing.

These drawbacks become less important the larger the radius of the through road curve, the more compact the arrangement of the component parts of a combination (points, crossing, cross-overs) and the lower the running speed.

The experience of several years has proved that the method is most useful in planning curved leading-in roads for station layouts and that it can even be extended to the main lines without serious practical drawbacks, by limiting its application to curves of radius larger than 250 m. (12 1/2 chains).

Considerations on the use of very long rails,

by H. FLAMENT,

Assistant Chief Engineer, Works and Supervision, of the French Nord Railway.

(*Revue Générale des Chemins de fer.*)

The growing weights of vehicles and increasing speeds on the important lines of the large railway systems has noticeably increased the fatigue to which the track is subjected. The use of metal coaches, of great rigidity and weight, has permitted of improvement in the comfort offered to passengers, by opposing increased inertia to the numerous small imperfections of the track. Against this, the latter has to withstand greater forces during the passage of the vehicles.

Fast running light railcars are particularly responsive to the condition of the permanent way, necessitating great care in supervising and carrying out maintenance work.

The track is a veritable runway the defects of which, above all any interruptions in its continuity, give rise to so many shocks to begin with, each constituting a source of disintegration of its constituent material. The joints between the rails form a weak point, as they leave a gap in the running surface, causing an inevitable blow between the tyres and the rail ends, the effects of which are the more harmful as weights and speeds increase.

It is therefore highly desirable to reduce the number of joints in a track carrying heavy, fast traffic, so that it may maintain its goods running qualities for the longest possible time. This can only be done by using rails of great length, the variations in the latter with temperature changes being able to occur without risk of endangering the stability and strength of the permanent way.

A number of engineers have devoted

their attention to this new problem for some ten years past, and it seemed to us that, owing to its opportuneness and importance, it was deserving of exposition and study, with a view to taking account of the solutions proposed or made use of, as well as of the various questions still remaining to be cleared up in this field.

The object to be attained.

The use of rails, practically limited so far to a length of 30 m. (98 ft. 5 in.) or so, has been due for a long time to the practical necessities of transport and handling and of permitting variations to take place without difficulty, as a function of the temperature changes.

The mean co-efficient of expansion of steel used for rails is 10.5×10^{-6} , and the limits of temperature attained in practice in France are -20° and $+60^{\circ}$ C. (-4° and $+140^{\circ}$ F.).

A rail joint must be regulated in such a manner that the ends of the rails may just come in contact at the highest temperatures, the greatest opening being found at the extremes of cold. It is therefore necessary to leave a space between the ends of 20 to 30-m. (65 ft. 7 in. to 98 ft. 5 in.) rails, which can actually attain a width of about 2 cm. (13/16 in.) during the most severe colds. This gap presents serious drawbacks as regards keeping the rails in good condition and maintaining the good running qualities of the track.

The number of joints can only be reduced by lengthening the rails and hence the size of the gaps between them,

which, if it diminishes the number of blows experienced by the track as wheels pass over it, increases their actual effect. Consequently the remedy may be said to be worse than the defect to be avoided. As a matter of fact, the hammerblows from the wheels can in the end produce deformation of the metal as well as start fissures leading to breakages, in particular around the fishbolt holes.

The alteration in the running surface affects the stability of the joint and the track in its vicinity. As soon as this happens, the only possible remedy is to replace the whole rail, which is expensive, or to build up the worn portions by welding.

It is consequently essential to avoid these drawbacks if very long rails are to be used; however, as long as the expansion factor of the metal remains near its present value the possible solutions to such a problem will be limited to two classes; viz :

— Either the size of the joint space must be reduced without the longitudinal stresses, arising from the compression or the expansion of the rails, resulting in harmful consequences for the track, or

— It must be arranged that the joint can freely and effectively absorb variations in the length without discontinuity being created in the running surface, which is harmful to the good preservation of the track.

These are the two practical solutions to the problem enunciated, consisting in :

— Either opposing the change in length of the rails by resisting it throughout the length of each one, overcoming it as it were by a suitable rigidity of the track, so that the latter can under all circumstances retain its stability; or

— Allow such a change to take place as freely but as regularly as possible, in selecting the track equipment in such

a way that the variation can be absorbed at the ends of the rails, without giving rise to blows and disintegration of the track.

A certain number of foreign railways have for some years been applying solutions of the first kind; the French lines have hitherto limited the length of the rails in their main lines and prescribed rules for laying and maintaining them, so that they may always expand freely in their fishings.

However, a number of investigations have been undertaken with the object of :

— establishing under what conditions a track is susceptible of becoming deformed and displaced under various influences;

— ascertaining the value of the resistance with which it can oppose them under present forms of construction;

— determining the correct means of increasing this resistance and avoiding all risk of deformation.

These investigations have comprised either theoretical study of the subject, direct trials and measurements, or actual applications deduced from the results obtained therefrom.

We shall summarize in succession such contributions made to the solution of the problem as have led to effective conclusions, data or practical results.

We shall then examine the consequences that may be drawn therefrom with regard to the general solution of the problems arising from the use of long rails under heavy and fast traffic, and endeavour to describe clearly the only results which may be regarded as definite, pointing out what further experiments may be taken into consideration for the purpose of providing solutions to outstanding questions about the whole question of safe train operation.

Investigating conditions of track resistance or deformation.

The German journal *Organ für die*

Fortschritte des Eisenbahnwesens published, in its issues for August 15th, 1928, and September 1st, 1929, two articles :

— one by Mr. NEMCSEK, engineer of the Hungarian State Railways, on rail expansion,

— the other, by Mr. D. WATTMANN, manager of the Electro-thermic Institute of Berlin-Tempelhof, on the influence of heat on a track laid with long rails.

The object of both articles was :

— to calculate the actual expansion in long rails taking all the restraining influences into account, and,

— to arrive at the value of the compressive force which could arise from fastening certain parts of rails immovably.

As a result of their examination of the subject, the authors conclude that the variations in length registered at the ends of 60-m. (196 ft. 10 in.) rails used on the German lines cannot reach those of the rails laid on the French lines, although the latter are markedly shorter. They think that the compressive stress resulting from the restraining effects which reduce the extent of the expansion of the rails can vary on the part of the rail considered to be fixed, in the vicinity of the centre, from 450 to over 900 kgr. per cm² (6 400 to over 12 800 lb. per sq. in.).

Mr. BATICLE, Chief Engineer for Roads and Bridges (France), in this investigation of the problem, after citing a number of articles treating similar questions, published in the *Génie Civil* for April 2nd, 1932, No. 14 (Vol. C), the conclusions he came to as a result of his calculations to determine what would be the effective variations at the joint gap width relatively to the temperature and the restraining forces in the track. The formulæ at which he arrived express what he terms the « delayed expansion of the rails ». He also believes that rail creep, which plays a large part in the

variations of the joint gap, originates in the hammer blows on the rail ends, from passing wheels. His conclusions concerning the conditions which will allow of observing the theoretical requirements for non-buckling of the track are as follows :

— the maximum length of rails compatible with the width of joint gap at present allowed is about 30 m. (98 ft. 5 in.).

— it is not possible to consider putting down 60-m. (196 ft. 10 in.) or even 45-m. (148 ft.), rails under present conditions of permanent way equipment, particularly with the maximum size allowed for joint gaps, without risking to compromise the stability of the track at high temperatures.

In the issue for August 20th, 1932, No. 8 (Vol. C. 1), of the same publication, Mr. Robert LÉVY, Assistant Chief Civil Engineer, French State Railways, reported on a mathematical investigation into the lifting action of the track — which he considers always precedes horizontal buckling — and into the value of the force which must come into play to produce such a phenomenon. He also makes clear his reasons for thinking it necessary to recommend great prudence in any possible increase in the length of rails, considering that experiments should first be made to determine the real displacements at the rail ends, to measure the actual restraining forces and, by a series of appropriate tests, to arrive at the effective value of the resistance to buckling. He explains the complex phenomenon of creep, by the succession of very small movements which the rails make, forwards or backwards, under the combined effect of temperature changes and the passage of trains.

Mr. MARTINET, Chief Civil Engineer, P. L. M. Railway, published at the same time in the *Annales des Ponts et Chaussées*, Vol. 2, No. IV, 1932, the results of a theoretical analysis of the probable causes of rail creep. The object of his in-

vestigation was to show that this phenomenon may be attributed to the changes in length which the rail foot undergoes on the passage of the vertical loads, and to the combined effect of braking, the blows between the wheels and rail ends, assisted under certain circumstances by a rise in temperature. The author estimates the force tending to movement at more than 7 500 kgr. per lineal metre (5 040 lb. per foot) of rail, while the resisting force arising from the friction of the rail on the sleeper or sole plate and the grip of the coachscrews is of the order of 2 300 kgr. (1 545 lb. per foot). He concludes that :

a) special devices are necessary to prevent creep;

b) a track will creep all the more easily that the axles are more heavily loaded, the sleepers further apart, and the modulus of resistance of the rail smaller, while compressible ballast, weak joints, bad fishings, and loose coachscrews will facilitate the process.

From the results of a theoretical investigation published in the *Zeitschrift des Vereins Deutscher Ingenieure* for October 6th, 1934, Mr. Herman MEIER, of Munich, considers that a temperature of 5° C. (41° F.) should be selected as the one for laying rails in the best possible conditions of equilibrium to meet subsequent temperature variations. He states clearly too that a judicious strengthening of the track, with certain precautions, would allow of the maximum stress to which the rails could be subjected being reduced to about 1 000 kgr. per cm² (14 220 lb. per sq. in.). Finally, he is of the opinion that the deformation of the track in which the joints have been abolished, whether brought about spontaneously or by a passing train, can only be avoided by laying it in a perfectly rigid condition and remedying alike the causes and consequences of creep.

In an investigation published in the April, 1936, issue of the *Bulletin of the*

International Railway Congress Association, Mr. CORINI, a professor at Genoa, considering what improvements might be made in the track by eliminating joints in order to make it suitable for very high speeds, makes certain reservations concerning the subject of Mr. BATIGNY's above-mentioned work, taking up and modifying some of his hypotheses. He arrives at the view that a preliminary heating of the rails is necessary, by means of a suitable electrical apparatus when laying them, so that they are subjected to tensile rather than compressive stresses as a result of changes in the surrounding temperature. Taking into account, in the second part of his study, the results of experiments undertaken to determine the various forces resisting longitudinal slipping of the rails and the track as a whole, he concludes that it is necessary to anchor the sleepers to the permanent way when it is desired to take advantage of the property of resistance to slipping possessed by certain signs of rail fastenings. He considers that, in general, such anchoring of sleepers in the ground and the laying of rails after preliminary heating should permit of welding rails indefinitely, thus completely abolishing rail joints.

Finally in a recent article in the November issue (2nd half year, for October, 1934) of the *Revue Générale des Chemins de Fer*, Mr. MARTINET examined in a purely mathematical way the conditions under which a track, assumed to be jointless, can buckle vertically or horizontally, and the stability of curved track. He particularly points out the rigidity which certain types of rail fastening can give to the track and indicates certain precautions which must be observed when carrying out maintenance work, as well as when laying rails without joints.

We shall see further on what remarks and reserves the views and conclusions of these various investigations suggest as much in their theoretical portions, as in the times developed at great length, as in

fundamental figures or elements made use of therein, in order to express the results in the form of practical conclusions concerning the constitution and behaviour of permanent way.

Measurements, experiments and tests made in connection with track deformation.

In addition to purely theoretical studies concerning the phenomena of track displacement and deformation, a certain number of experiments have been conducted to analyse the features of the various phenomena noticed, and evaluate the true magnitude of the resistance to deformation. These experiments have consisted of measurements made on certain test lengths of track, either permanent way in normal service, or sections specially arranged for carrying out systematic tests up to complete buckling of the track. We think we should give a chronological summary of these tests, as we did for the theoretical investigations, in order to note the principal results achieved or recorded.

Mr. BLONDEL, Chief Maintenance Engineer, Paris-Orléans Railway, published in the December, 1932, issue of the *Revue Générale des Chemins de fer*, the results recorded during experiments on that System. Their object was to determine approximately the value of the resistance offered by the track to the hunting of vehicles by measuring the value of the forces necessary to produce lateral displacement. The forces applied resulted either from pressures or from blows on some lengths of track specially arranged for the purpose.

In the first case track laid with standard type rails, 46 kgr. per metre (92.7 lb. per yard), as used on the French main-line Systems, was loaded with a stationary double-bogie vehicle, axle load 19 tons, and was only slightly displaced under a pressure of some few tons, but was completely moved as soon as it reached some 20 tons. Subjected

to lateral blows the same track tended to become securely fixed after a few displacements, if these did not exceed, say, 10 mm. (3/8 in.). The results produced depend almost entirely on the total quantity of energy brought into play. The author concludes that the lateral resistance of the track may be characterised by « the critical force ». This is such that all lateral forces of lesser value only cause practically negligible side slipping, while the track becomes markedly deformed the moment this thrust exceeds the critical force. This transverse resistance is clearly greater in a well bedded track than in one in which maintenance work has just been effected that has modified its seating.

In the issue for March 15th, 1932, No. 6, of the *Organ für die Fortschritte des Eisenbahnwesens*, Messrs. O. AMMANN and VON GRUNEWALDT gave the results of experiments made at Karlsruhe, to arrive at the actual value of the moment of inertia of a track fixed on its sleepers, of the stresses due to expansion of the rails and the resistance which the track can oppose to the forces which, compressing it longitudinally, are apt to cause buckling. Thanks to the use of suitable apparatus, the buckling of certain parts of the track, secured at one end, was obtained several times, by the application of powerful presses. Although these results only apply to the conditions under which the experiments were made, to which we shall have occasion to refer again, we think we should shortly summarise them.

On straight alignment, buckling of the track of the so-called Baden pattern, formed of 12 m. (39 ft. 4 1/2 in.) rails on metal sleepers occurred when the compressive force reached 180 to 200 tons. It began in the vertical plane and the track so raised dropped sideways in several places.

During similar experiments repeated on a curve of 260 m. (13 chains) radius a lateral displacement towards the out-

side of the curve beginning at about 160 tons pressure was recorded. With track type K of the German State Railways, the corresponding deformations only occurred when the pressure exceeded some 220 tons with wooden sleepers and 240 tons with metal sleepers.

As a result of these experiments, the authors conclude that there can be no thought of reducing the risks of track deformation as long as it will not be possible to reduce the rail temperature variations, as for example, by embedding the rails in ballast, or to notably increase the weight of rails, or again to increase the resistance of the track to lateral displacement by strengthening it by means of appropriate anchoring.

The same writers later stated in issue No. 5 for March 1st, 1934, of the same periodical, that the resistance to longitudinal and lateral displacement varied from about 0.8 to 2.0 tons per sleeper, according to the design of the track. This latter figure has been markedly exceeded, especially as regards lateral displacement, by adding metal stop pieces to the ends of the wooden sleepers.

In the issue for March 15, 1933, No. 6, of the same journal, Mr. NEMCSEK, already mentioned, gave the results of some experiments made to arrive at the value of the various elements making for track stability. On some experimental lengths, where there was no traffic, measurements made under purely static conditions, showed that displacement began with a longitudinal pressure of about 200 kgr. per lineal metre (134 lb. per foot). Only at the end of the movement was the figure of 500 kgr. (335 lb.) reached, which was quoted by Messrs. AMMANN and VON GRUNEWALDT in an article in *Organ*, in 1929. He concludes from certain observations, that the track offers a progressive resistance to creep, springing from very complex laws, following the frictional effect of the various track components. As regards lateral resistance, this depends on the

type of equipment, on the nature and depth of the ballast, and whether the line is carrying a load or not. The figures found vary, in practice, between 0.4 and 1.0 ton per sleeper. Taking into account a certain amount of data provided by authors already cited and of certain others, especially the longitudinal resistance arising from friction at the fish-plates, varying from 10 to 40 tons, he deduces, from the measured amplitude of certain displacements, the value of the forces required to produce them. After experiment he gives 50 tons as the approximate longitudinal pressure required to start buckling in a 60-m. (196 ft. 10 in.) length of track, laid simply on a roadbed of ballast levelled but not compressed.

Beyond this figure the track commences to show a slight rising movement before the lateral displacement in S form sets in. This force must reach some 100 tons in the various types of permanent way laid under conditions bordering the normal.

In order to ascertain the conditions under which a track in normal service experiences the combined effects of temperature changes and creep, the French Railways made a series of observations, records and measurements during two test periods from September 1st to December 1st, 1931, near Etampes, on the Paris-Orleans line, and from December 10, 1933, to December 15, 1934, near Villeneuve-St.-Georges, on the Paris-Melun line, both these main-line sections carrying heavy expresses. The first was seven years old track laid with standard type 46 kgr. (92.7 lb. per yard) rails, 16.51 m. (54 ft. 2 in.) long, on 27 sleepers, the second track was 9 years old, with L. P. type, 48-kgr. (96.8 lb. per yard) rails, 18 m. (59 ft. 5/8 in.) long on 31 sleepers.

The use of various measuring devices made it possible to obtain a continuous record of the temperature, the width of the joint gaps, the position of the ends

and the centre of a certain number of selected rails in each section, while measurements were also made for check purposes on entirely free adjacent rails.

The collected results made it possible to see that, with permanent way equipped and maintained like the French main-lines, the position and length of the rails can never be defined in terms of known factors, particularly of their temperature. They depend on the conditions under which such factors have varied previously, and on material influences, difficult to know and determine, such as the tightness of the coach screws and fishbolts, conditions of the ballast and maintenance, finally on the very complex action produced by passing trains. The records made of the displacement at the rail ends shows that it only occurs as trains pass. No law is deducible from these observations.

It has, however, been recognised that the practical rules in general use on the French Railways, and put in force 6 years ago, were efficacious and justified by experience. The adjustment of the joint gaps made every year before the warm weather, the fixing of their size at such a figure that it can only be reduced to nil at a maximum temperature of 60° C. (140° F), the duty placed on the maintenance staff to re-establish it as soon as, at lesser temperatures, successive gaps are closed up over at least 50 m. (164 ft.) allow of suitable stability being maintained, affording every safety for the traffic.

Observations show that track only takes up a condition of equilibrium, as regards length and position of the rails, in the course of temperature changes, in a very slow and gradual fashion. In any case, the length, when the rails have reached such a state as a consequence of a sufficiently stable temperature, agrees with the application of the co-efficient of expansion, rated at 10.5×10^{-6} , used as a basis for determining the joint gaps.

Trials of long rails in service.

As a supplement to the above information we propose to mention certain instances of the use of long rails in main lines, from among the most characteristic or extensive brought to our notice.

A few isolated experiments in France may be noted, such as the 44-m. (144 ft. 4 in.) rails laid in 1932 on the Midi Railway, formed from two 22-m. (72 ft. 2 in.) rails fished edge to edge at one end. Since 1935, the Nord Railway has put down, in locations others than on metal bridges or in tunnels, some 35-m. (114 ft. 10 in.) rails with skew joints, fitted with special fishplates tried for the purpose of facilitating the displacement of the rail ends.

In tunnels most Railways have put down rails the length of which increases as they get further from the portals and has been made as great as 288 m. (945 ft.) on the Nord, in a tunnel near Boulogne, where the nearness of the Channel notably diminishes the temperature variations.

Many foreign Railways, especially the German State Railways, have considered it possible to reduce the usual width of the joint gap, adjusting it so as to leave the rails in a state of equilibrium, neither in compression nor tension, the joints being merely closed up, at a suitably selected temperature between the highest and the lowest possible. The track is assumed capable of resisting the forces of compression or tension produced by subsequent temperature changes. For ten years past the German lines laid with rails of 30 m. (98 ft. 5 in.), or in exceptional cases 60 m. (196 ft. 10 in.), have been put down and maintained in this manner.

The Belgian National Railways Company has for seven years been trying similar arrangements all over its lines, particularly with the 54-m. (177 ft.) rails laid in 1934 between Brussels and Antwerp. Mr. LEMAIRE, Chief Civil En-

gineer, had occasion to set forth in a detailed report, prepared for the International Railway Congress in Paris, in June 1937, some of the observations made with this track, in which rails were secured to the sleepers by very rigid fastenings. With fishbolts slackened the expansion of the rails under a temperature change of 25° C. (45° F.) was much less than the theoretical figure, while variations in length were practically nil in the centre of the rail and substantially symmetrical with respect thereto.

Other experiments, of a much more limited kind and of an exceptional character, have been made to form very long continuous rails, either in tunnels or out in the open. The German Railways put down in a tunnel a section of continuous track formed of rails welded end to end for 2 000 m. (6 560 ft.). The Yugoslavian and Danish State Railways have gone to 1 200 and 1 300 m. (3 937 and 4 265 ft.) in like circumstances. As far as we know, a 1 000-m. (3 280 ft.) length in the open on the Egyptian lines and one of 2 124 m. (6 900 ft.) on the Delaware and Hudson Railroad in America, have been tested.

Later on we will return to these practical tests of track in which the joints have been eliminated or at any rate reduced in number.

The problem of long rails.

The problem to be solved is to ascertain the conditions under which long rails can be laid and maintained, with no risk whatever of becoming buckled by the combined influence of temperature changes, creep and traffic. The extent of the investigations made for this purpose, the importance and extent of the experiments undertaken, represent a considerable effort to reduce, for the reasons given above, the width of the joint gap and the number of joints. We propose to consider to what extent these investigations and tests have effec-

tively contributed to provide possible solutions of the problem and what practical conclusions may be drawn from them at present.

Critical examination of investigations and experiments.

In the first place we will separate investigations and experiments properly speaking from trials carried out on the line under traffic, such as those briefly mentioned above.

The first have been practically confined to the static stability of the track. Measurements made when vehicles pass at trial speeds far removed from those found in practice can hardly be applicable to the case of lines traversed at high speeds by vehicles subjecting them to considerable dynamic effects. At the most, the data obtained and the conclusions drawn from them could only concern tracks supporting very limited stresses such as sidings, or lines inside stations, only run over at low speeds.

Certain Railways, in fact, such as the Nord, who have laid a large number of welded rails of some hundred metres in length in sidings have never met with any trouble caused by passing trains.

Such improvements, already the cause of appreciable economies in sidings, should be even more valuable on lines with heavy traffic. The wear and tear to which rails on important lines are at present subjected hastens the time when they must be discarded because of the deterioration of the ends, necessitating frequent and expensive maintenance. It is also on such lines that the presence of joints and the small defects in the track which start at or near the rail ends lead to consequences most prejudicial to the running at high speeds, and here no solution has been offered to the problem of abolishing the joints or reducing their number. Beyond the few isolated cases mentioned above, no railway has attempted to extend to main line sections the solutions applied to, or

proposed for, sidings, and the problem of long rails on main lines still awaits solution.

Some examples of little known elements entering into the behaviour of railway track.

Let us first of all see why the results of most of the investigations quoted have not yet provided any solution to the long-rail question.

As a matter of fact, most of them were carried out under artificial circumstances, neglecting the influence of certain little known elements, difficult to determine hitherto with exactness.

Notwithstanding that vehicles are fitted with springs and other suspension gear, compensating devices, etc., to counteract the blows and sudden stresses produced as they pass over the track, the latter must, rigid as it is, absorb equivalent reactions at the expense of its stability and the preservation of its material.

The way in which the rail ends are hammered by the wheel tyres is still somewhat obscure. It would appear that either a direct blow occurs, or a rebound of the wheel as it traverses the gap.

This either crushes the rail end, or forms a hollow, the position of which varies according to circumstances and appears to get further from the joint as speed increases. This cold-hammering produces progressive deformation of the rail head representing a considerable amount of work, the result of the expenditure of a good deal of energy.

This series of blows may possibly explain the phenomenon of creep, but its complexity has so far not allowed of that being clearly proved, and we must add that the theory that creep is caused by the variation in length of the rail as each axle passes cannot be explicitly proved either. The fixity of the sleepers is, in fact, only an exceptional

thing and the function of the ballast is not only to support the sleepers but also to give the track a certain amount of elasticity, indispensable for keeping it in order and preserving it.

So too, the somewhat complex theory which attributes creep only to temperature changes, combined with train movements, cannot be justified in every case and can no more be proved experimentally than the two preceding theories.

In any case the passage of vehicles causes passing deformation of the rail, vibration and slight lifting of the track, varying from one section of the line to another. The least irregularity in level often produces a blow or shock which accentuates the original defect, and is complicated by a lateral effect acting on the track and pushing it out of alignment. Such an action can suddenly upset a condition of unstable equilibrium due to an unexpected and too rapid expansion of the rails.

The hypothesis which assumes a track in a condition of rigid equilibrium, perfectly levelled and aligned, carried on supports regarded as fixed, often runs the risk of falsifying the reasoning and conclusions of an investigation into track stability. Even if the running conditions are practically perfect, the track nearly always suffers, as a vehicle passes, a sort of impact effect, already noticed on such structures as bridges, as a result both of the elasticity of the layer of ballast and the roadbed. This effect has been found at times to approach that due to the static load of a vehicle. It is apparently to an action of this kind that is due the appearance of defects in level in the actual body of the rails, whatever their length, and more rapidly on a high-speed line than on a secondary line, even where traversed by the same vehicles.

In addition the wheel tyres produce lateral actions on the track, the amount of which is only just now being appre-

ciated by means of appropriate appliances and has been known at times to reach ten tons.

Even in the purely static field, to which some engineers had to restrict their studies and experiments, though often of a searching nature, the conclusions they have come to are often falsified, because they assume, in the majority of cases, basic figures which must inevitably be somewhat arbitrary.

The co-efficients of friction between rails, fishplates, soleplates, sleepers or ballast are imperfectly known and, above all, very variable. Their influence is, however, of prime importance, and conclusions drawn from formulæ in which they are made to figure are often contestable. The proportionate size itself of the figures which are arrived at may not always be grasped sufficiently to enable the risk of buckling to be truly appreciated.

It is difficult to conceive besides, in spite of the theory of equilibrium of a track in compression, worked out and explained in Mr. Martinet's above-mentioned article, that if an excessive lift is liable suddenly to change into buckling, the track can nevertheless be raised some ten centimetres (4 inches) by the maintenance staff without danger and replaced in its original position before trains pass.

The process by which a track is buckled is not the same when it is brought about artificially on a test piece of track as when it happens on a line in service under local influences. Though it is most likely that buckling is always preceded by a lifting of the rails and sleepers, the latter has never in practice—save perhaps in a few exceptional cases of track settlement in mining districts—attained the form and extent noted during the experiments referred to.

In a track which is in use, from the moment when it lifts under a longitudinal thrust, it can free itself from com-

pressive stress by a slight movement in the opposite direction to the latter which can thus spread itself along the line. It can even be conceived that it may become displaced under the action of passing trains or of creep until the play allowed by a joint cancels it by permitting the compressed rail to expand freely, or at times until it meets a fixed point such as some points of crossings, a bridge girder, a level crossing, etc.

Now, in the various experiments that have been made the track is always limited by two stops, one fixed, the other where the increasing pressure is applied. The thrust arises therefore between, and starts from, two definite points, whereas it actually ends there whilst developing and moving under various influences, particularly the effect of passing wheels.

These variations and displacements of driving forces are in any case of such a character as to modify the free condition of the rail, laid in a condition of equilibrium by suitable adjustment of the fastenings and joints.

Be that as it may, however, it appears likely that deformation due to expansion of the rails is preceded by a slight rise of the whole track which, scarcely perceptible though it may be, by lifting the sleepers from the hollows and ridges of ballast keeping them in place, facilitates horizontal buckling, allowing the track to move sideways more easily. Observations made by maintenance men when they have chanced to be present at the onset of buckling confirm this hypothesis. This does not, however, appear to be the case with buckling that occurs as the last vehicles of a train pass, the locomotive and first vehicle having passed over the section of track concerned without anything happening. Consequently, it seems that no exact general rule can be laid down in this matter.

The conclusion to be drawn from

these observations is that a track, subject constantly to diverse and varying stresses can rarely, notwithstanding its excellent stability, be considered as in a condition of rigorous equilibrium and completely at rest.

The track laying and maintenance regulations in force on the French railways are based on this view. They always aim at leaving enough gap between the rails to permit the latter to expand fully at the highest temperatures experienced in hot weather. In other words « safety valves » are provided at short intervals which enable the joints to « breathe », by giving way to excessive pressures apt to distort the track. It is essential, moreover, that the condition of the fishplates, particularly the tightness of the bolts, should not prevent the rail ends from moving in the fishing.

The irregularity that cannot fail to be noticed in the size of the gaps expresses the resistance which the fishplates and the frictional effect of sleepers and ballast oppose to the expansion of the rails. A fishing, however, which does not allow its joint to « breathe » causes no other in the vicinity to do so where the frictional hold of the fishplates is less. It must be acknowledged that these arrangements allow of safe running at the highest speeds and in very hot weather, in spite of temperature changes attaining the limits fixed in practice, at least in a good many districts.

This result and the reasons which led to it suggest great prudence in considering those important modifications that have at times been suggested in the construction and maintenance of the track, the reduction of the number of joints, and the process of adjusting the gaps.

When rails are established in a state of equilibrium in well defined conditions, the effect lasts only a short while. They are subjected to considerable and varying longitudinal forces, and may come to contain abnormal compressive stresses, invisible to and unsuspected by

the maintenance men, if no joint can take them up at one end of the affected zone.

The problems still to be solved.

Under these conditions then, must it be concluded that it is impossible to use very long rails for high-speed lines? We do not think so and continue to be convinced, for reasons given at the commencement of this article, that we should persevere in this direction, all the more that the almost continual increase in speed and loads, as well as the extension of fast railcar services, make the problem of reducing the number of joints of immediate importance and special interest. However, it must be acknowledged that no railway has yet done more than make a few limited experiments in the matter.

It is quite evident that it will not be possible to draw up practical conclusions before the behaviour of a certain number of sections equipped with very long rails, variously placed and carrying different kinds of traffic, and very carefully inspected and watched, shall have confirmed that no risk of mishap will result from the arrangements adopted. It is indispensable, in particular, that the observation period shall be long enough to cover very extensive changes in temperature and atmospheric conditions: very hot days, rapid temperature changes with the maxima met with in actual practice, prolonged exposure to the sun, etc.

Trials of any importance with long rails on main lines have been, as we have seen, either on track laid in tunnels, or with rails scarcely exceeding some 60 m. (196 ft. 10 in.) in length.

In the first case the very limited temperature changes practically exclude all risk of such mishaps as might be feared in the open. In the second it seems that those responsible have not so far been inclined to generalise their experiments.

The three very elaborate reports

which were published before the last meeting, in Paris, of the International Railway Congress Association contain all the particulars relating to the position on the various Railway Systems regarding rail welding and particularly the building up of long rails. The problems involved, the particular points brought out and results obtained are set forth in these reports, written by Messrs. MÜLLER, ELLSON, and RIDET, and published in the *Bulletin* for November 1936 and January, 1937.

A general résumé of the observations and conclusions offered in the three papers was made by Dr. MÜLLER and printed in the *Bulletin* for June, 1937. The conclusions adopted by the Congress were published, with a summary of the discussion, in the *Bulletin* for September, 1937, while the detailed report of the discussion on this important question was given in the issue for December, 1937. The reader can usefully turn to these various investigations, which form a particularly valuable, complete and up to date collection of information, showing just what results have been obtained by the railways interested in these matters.

It seems quite impossible to formulate any firm conclusions on long welded rails. Trials are continuing, in some cases on a large scale, under close attention and justifiable caution; but nothing as yet allows of positive conclusions on the use of very long rails, save in tunnels.

We may also mention a long account of the results obtained in 1936 on the German State Railways, published in the issue of January 6th, 1937, of *Die Reichsbahn*, which is satisfied with stating shortly that the researches and experiments made with long rails are not yet completed.

Summing up, we may say that the Railways who have reported the isolated or limited use of very long rails are content to keep their tracks under observa-

tion and follow the results of the experiments in progress. A well justified feeling of considerable prudence in the matter, is therefore to be noted.

The lesson of the experiments.

We will nevertheless endeavour to say if it is possible, taking recorded results into account, to determine some of the conditions and precautions which permit of the safe laying of long rails on high-speed lines, which are those where the reduction in the number of joints is most valuable.

The use of moderate [say 50 m. (164 ft.)] length rails would not, it seems, bring us to decisive conclusions. It is plain that in a track laid with 24-m. (78 ft. 9 in.) rails, for example, common practice on several railways, the unexpected closing up of a joint is equivalent to the presence of a rail twice the length, as regards the behaviour of the track, and experience proves that no disadvantage results from present rail lengths. We may therefore conclude that 50-m. rails would involve no risk if we could fix them solidly in the centre and leave the ends free to expand. It would evidently not be possible to go beyond that and simply multiply by two the length of rails, selected from among the longest used at present, without short of sufficient experience in the matter, running the very risks it is sought to avoid.

Experiments with rails more than 50 m. (164 ft.) long are relatively limited. The very extensive use made of 54-m. (177 ft. 2 in.) rails by the Belgian National Railways Company, during the last two years on the electrified Brussels-Antwerp line is as yet too recent to enable decisive conclusions to be drawn.

The German State Railway engineers who used, some few years back, sections of 60-m. (196 ft. 10 in.) rails do not appear to have gone on with the matter of years, or to have had occasion to state reasons for limiting or extending trials.

Our own findings on the Nord Railway may be summarised as follows :

In holding sidings laid with 100-m. (328 ft.) long rails in many places the variations in length recorded are notably inferior to those which would follow from an application, pure and simple, of the formulæ for expansion of the rail metal. It is found besides that a considerable portion of the body of the rail maintains an almost constant length. Only the portions near the ends give way under the stresses arising from expansion and contraction and cause some displacement in the joints. It appears possible to conclude, considering the very careful fixing of the centre portion of each rail to the sleepers, that the very compact nature of ballast in sidings, the absence of all maintenance work likely to give some degree of mobility to the track, do not in practice allow external influences to modify its equilibrium and fixity. The track, thanks to the exceptional way in which it is restrained from moving, and to the absence of blows or large dynamic effects, as vehicles pass, since they only move at low speeds, undergoes the variations of compression and tension due to temperatures changes, without their appearing in any way other than in the neighbourhood of the rail ends, these being relatively free owing to the presence of the joints.

One fact may be noted. No creep occurred in lines laid in these conditions. Of the absence of high speeds, accentuated reactions, and blows at the joints, may be regarded as an appreciable cause of creep, the circumstance was nevertheless deserving of remark.

On main lines in tunnels, equipped with, in some cases, 288-m. (946 ft.) rails, the same circumstances have been noted in every respect. These rails also were carefully secured in the middle by anti-creep fittings against movement in their direction, fitted each side of a certain number of sleepers, and only

showed very small displacement at their ends. This may be attributed to the small temperature variations in the tunnels concerned, practically between -2° and $+20^{\circ}$ C. (28.4 and 68° F.) and the precaution taken to adjust them in situ at a temperature of some 15° (59° F.).

Under these conditions the displacements of the ends were always less than anticipated, and were limited to about one fourth of the figures for the theoretical expansion of the entire rail. These variations were substantially equal at each end, although the two lines of rails were on a main line, traversed daily always in one direction, by express trains, hauled by some of the heaviest and most powerful locomotives on the railway, running at high speeds, frequently as much as 120 km. (75 miles) per hour. No creep appeared with these rails; the centre portion of each rail remained practically stationary, no displacement being noticed since they were laid, the oldest some four years ago. What can we conclude from these facts ?

Guarding ourselves against hasty generalisations, we believe ourselves justified in thinking that on tracks where changes of temperature are relatively small, long rails secured in their centre and laid and adjusted at a suitable temperature, will remain practically in their original position of equilibrium.

The explanation of this appears to be that the temperature changes, limited in practice to some 15° C. (59° F.) beyond that obtaining when the track is laid, do not give rise to sufficient longitudinal stresses to compromise stability. The absence of all joints obviates the disturbing effect of passing wheels and does not allow any excessive tensile or compressive stresses to move and accumulate along the rails. All possible cause of creep appears to be eliminated and the rail, in this respect, stays completely stationary.

Although we have not obtained exact information on the subject, it seems pos-

sible similarly to explain the satisfactory behaviour of some very long rails. Such is apparently the case with the 1-km. (0.62 mile) trial length, reported by the Egyptian State Railways, for this was doubtless laid in a region where the temperature varies comparatively little, up or down, from that at which the rail was laid, and which must have been carefully selected.

Practical considerations governing the use of long rails.

From what has been said it appears that long rails could be safely used on high-speed lines under the following conditions :

The site should be selected, according to position and local conditions, so that temperature changes do not exceed some 20° C. (36° F.). There will be no need to arrange for a very large expansion gap at the rail ends, nor to fear that the temperature changes may give rise to longitudinal stresses endangering the equilibrium and stability of the track, provided the two following conditions are observed.

The middle of the rail should be immovably secured, over a space of a few metres, by fixing it solidly to the corresponding sleepers, and the latter, if possible, to the roadbed. This allows longitudinal stresses to distribute themselves as regularly as possible on either side of the fixed central point and prevent them reaching an excessive figure.

The rail should be laid, and conditions of equilibrium in it obtained, with suitable adjustment of the fastenings and outer joints, at a temperature carefully selected between the limits effectively attainable in practice. This precaution is to ensure that the rails will never be subjected to excessive longitudinal stresses.

On the French Railways the use of very long rails on lines traversed at some speed cannot at present be contemplated, under such conditions, save

in tunnels, where temperature changes are in practice very restricted.

Further experiments required.

What more is possible in this direction, with the object of safely using very long rails outside tunnels?

To avoid all risk of track buckling is indispensable to have some means of absorbing variations in the rail length in time, before excessive longitudinal stress is created.

The first condition to meet therefore is to join the rail ends by a device which allows them to move easily, or in other words to make not merely a connecting joint, but an actual expansion joint. Such a joint should also give rise to the smallest possible hammer blows when wheels pass over it, to ensure the track remaining in good condition and equilibrium. This is all the more necessary because the replacement of long rails on account of wear at the ends would be markedly dearer than with short lengths and, if it could not be avoided, would render their use prohibitive. This first condition is, so to speak, purely mechanical problem, and should it be satisfactorily solved, there would still remain another no less urgent.

Such a connecting and expanding joint will only be useful and efficacious if the variations in rail length are transmitted fully to the ends, without giving rise to excessive longitudinal stresses in the rails, unable to reach a joint which can absorb them.

This is where the new problem arises, the investigation of which is essential, for it has as yet not been entered on in a practical manner. It amounts to this : up to what length and under what conditions are the stresses due to expansion and contraction under the effect of temperature variations always able to distribute themselves along the rails as to reach the ends before reaching a value dangerous to stability of the track.

It is easy to see that, if this length were known and sufficiently confirmed by experience, it would be possible to consider, without any risk, the use of rails of the ascertained length. The centre one being fixed securely, variations in length could take place without hindrance on both sides, throughout the rail. If the latter were provided with a suitable assembling and expansion joint, the movements of the ends could be taken up there without dangerous longitudinal stresses arising.

It is here, we think, that further experiments are required in order to determine how far the present tracks can effectively meet the case, taking into account the various factors involved, such as section and weight of rail, number of sleepers, type of fastenings and nature of the ballast, methods of refitting and maintaining the track, etc. Until such fundamental data is obtained with certainty we must take it that long rails cannot be used on high-speed lines without a risk that one day unfavourable conditions will accumulate at one point, along a section of the track, and bring about its distortion, without anyone being able to foresee it and take preventive measures.

To carry out such experiments it is necessary to take into account the actual conditions under which the rails would have to work, that is undertake them on lines carrying fast traffic, where the track is subjected to all the stresses it must be capable of withstanding. This means that such experiments must be carefully watched and cautiously carried out. As soon as an efficient expansion joint is available, it will be possible to consider making trials on lines carrying heavy traffic, beginning with rails slightly longer than 50 m. (164 ft.), fitted with joints allowing them to move freely at the ends, and laid for observation purposes on the main lines. The length should be gradually increased as experience

is obtained, and as observation of rails in service allows of it.

It is, of course, understood that these trials, undertaken in systematic and progressive fashion, must be made under as varied conditions as possible as regards local conditions of layout and gradient, of traffic : speed, loads and braking action, etc. A number of experiments is necessary to avoid one or several variable factors being left out of account, or factors the influence of which might not be suspected or be wrongly neglected. The trials should also extend over a certain period, so that the rails shall be subjected to numerous and varied temperature changes, taking advantage of the years where temperature is highest and, above all, its variations sudden, in order to note carefully the behaviour and expansion of the rails.

The centre of the rails should be secured as firmly as possible and their behaviour observed in particularly favourable cases as, for instance, where the central portion comes on some bridge or on a level crossing, forming a definitely fixed zone, completely holding the corresponding piece of track.

Researches need also to be made on the track fittings, properly so called, especially the fastenings between the rails and sleepers. It is difficult to believe that the rails are not now fixed in the most rigid way possible, both in France and on the majority of the European Railways. The maintenance and inspection of the fastenings, and their tightness, the elimination of all hammering and all movement of the rail with regard to the sleepers is one of the most fundamental rules observed in permanent way work.

However, on the greater part of the American lines, carrying, like those in Europe, a heavy traffic, the idea of rigid fastenings keeping the rail constantly bearing fast on the sleeper or intermediate sole plate, for a long time remain-

ed unknown. It would appear that such construction should allow long rails to expand and contract more easily, the centre portion remaining suitably held fast. This conception, somewhat disconcerting *a priori* in view of the idea which a large number of railway engineers entertain as regards the construction of the permanent way, should not, it seems, be set aside. Here again experiments alone, judiciously carried out and extended on the basis of a sufficient number of observations, would perhaps enable one to tell what can be derived from such a suggestion.

We have mentioned it in any case to

emphasise that in our opinion the problem of long rails will not be solved, as has been attempted hitherto, either by strengthening the track equipment, or by merely checking rail expansion by suitable devices.

On the contrary, we believe that it is in facilitating it and regulating it along the line, suitably equipped to absorb it without the least hindrance, that a satisfactory solution of this problem will be found, a problem which, owing to present-day conditions and requirements of the traffic, is now among the foremost occupying the attention of the permanent way engineers.

[625. 162 (.73) & 656. 259 (.73)]

Efficiency of crossing protection.

An extensive study of the human and mechanical factors involved in accidents at railway-highway intersections,

by WARREN HENRY,

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(From *Railway Age*.)

Apparatus for protecting railroad-highway crossings has been developed to a high degree of mechanical reliability but, to be effective in preventing accidents, the devices must work in conjunction with human reaction. Therefore, in any study of the promotion of safety at crossings it is necessary to consider the human as well as the mechanical aspects.

In discussing crossing accidents, most people are likely to attribute the causes to two types of drivers, (1) those who deliberately disregard warning indications, and (2) those inattentive drivers whose minds are concentrated on other

(*) An abstract of a paper presented before the Western Society of Engineers, Chicago, on November 29, 1937.



Typical flashing-light crossing signal.

matters. Accidents attributable to other causes, however, are happening all the time and our problem is by no means as simple as would appear if we had to deal only with the two conditions mentioned above.

Reckless driver a hazard to other persons.

Considering for a moment the accidents caused by reckless and inattentive drivers, an argument is sometimes advanced that the misfortunes of these drivers are attributable to the drivers themselves, and that neither public authorities nor the railroad should be particularly concerned with the prevention of such disasters. On the contrary, the prevention of accidents at crossings is not merely a matter of protecting an individual driver who may himself be at fault, but is clearly a matter of public interest and public safety, because, not infrequently, such accidents cause trains to be derailed. For illustration, a coupe driven by a woman was struck by a passenger train at a crossing, causing the locomotive and the leading cars to be derailed and killing not only the automobile driver, but also three men in the locomotive and two persons in other parts of the train, while many others were injured, and property damage of about \$ 100 000 was incurred.

Other factors involved.

Consideration should now be given to accidents in which the driver cannot be criticized for being reckless or inattentive, but in which the misjudgment of conditions or failures of a human or mechanical nature were involved. In some instances, evidence indicates that a driver simply misjudged his own speed and requisite stopping distance and, while knowing of the hazard and doing his best to stop, he found himself nevertheless unable to make a stop in the distance which he has allowed. Another common case is that of the night

driver who outrides his headlights, that is, he is unable to stop in the space available after he discovers, by his headlights, a dark train across the road ahead. Before we condemn this driver too much, let me say that tests conducted by our state highway department tend to indicate that many of us are inclined to be guilty rather habitually of this fault of outriding our headlights.

Again, as illustrating human failures, let us consider this type of accident: A man, age 73, was driving alone in his car and was approaching a crossing when a train was observed to be also approaching. According to witnesses, the driver of the car evidently saw the approaching train but his actions were such as to indicate that he became confused and in the end, he stalled his automobile directly on the crossing, with the result that he was killed. This was not a case of recklessness or of inattention, but was rather one of the not-uncommon situations of confusion or panic which result in an accident.

We may also classify, to some extent at least, as human failure the type known as the two-train accident. The most usual form of this arises where a driver awaits the passage of one train at the crossing of a multiple track railroad, and, immediately upon the passage of that train, drives forward into the path of a second train approaching upon another track concealed from view by the first train.

The human failures, therefore, may be summed up as including, as major factors, recklessness or intoxication, inattention, misjudging of distance and speed, outriding headlights, confusion or panic, failure to appreciate a possible two-train situation, and failure, on the part of an employee, to perform his duty. Physical conditions such as storms, ice or snow on the pavement, frost on the windshield, dazzling headlights of other cars, sharp approach grades, obstruction to view, and the like,

are also clearly major factors in many accidents.

Distribution of accidents.

Accidents are not, for the most part, concentrated at a few important and heavily traveled crossings. A large percentage are spread out over the numerous country road crossings, crossings of city and village streets, and other crossings not on the main roads of travel. A study was made of accidents reported to the Illinois Commerce Commission by the Illinois Central, covering a period of five years from 1929 to 1935, inclusive. On 1 809 miles of lines covered by this survey, there were 2 910 crossings, or an average of one crossing for each 0.6 mile of line. During the five-year period, 549 reportable accidents occurred and these were distributed among 376 crossings. Designating these 376 as « accident crossings », we found that 89 % of them had no more than one or two reportable accidents in the seven years, 10 % had three to five accidents each, and only 1 % had more than five reportable accidents. In other words, nearly 90 % of the accident crossings were the scene of casual and infrequent accidents, and, conversely, the accidents themselves were for the most part distributed among crossings which individually would not be deemed to be points of very great hazard, upon the accident record at least.

The cost of grade separations varies greatly, but will average approximately \$ 50 000 per crossing. Grade separation projects to eliminate all of the 18 000 crossings in Illinois would be a manifest impossibility within any reasonable length of time because a total expenditure of some \$ 900 000 000 would be required. If all of the crossings in this state were to be protected by automatic flashing-light signals or some comparable means, we would still contemplate a total expenditure of about

\$ 45 000 000. Bear in mind that many of these crossings are on country roads and village streets which carry light traffic but nevertheless, in the aggregate, can be depended upon to produce a large portion of our total number of crossing accidents.

Protection of minor crossings.

This suggests the problem of developing protective methods, means, apparatus, or traffic control measures, suitable to these numerous so-called minor crossings, and which will actually work in practice. Someone may suggest the use of stop signs or stop regulations as an obvious measure. In theory this is good, but past experience with such measures in this and other states is not encouraging. Plain common sense, on the part of the public, might appear to be a sufficient answer. But, as a safety measure, supposed common sense is a most dubious thing upon which to rely. We deal with human beings, and it is no answer to wish, or suppose, or expect that human nature is different than what actually is. The problem of these minor crossings has been given careful study by various organizations, including the staff of the Illinois Commerce Commission. Tangible results appear to have been achieved to a greater extent in the mechanical than in the human aspect, particularly in the improvements in marking signs.

At several hundred crossings in Illinois, fixed crossbuck signs of an improved type have been installed. An outstanding feature is the use of reflector buttons in both the front and rear faces of the sign. The so-called rear indication has several advantages. A driver approaching the crossing at night sees two illuminated crossbuck symbols, one on each side of the highway. This gives a sort of « gateway » effect which tends to accentuate the place on the highway thus marked.

Furthermore, the view of the sign on the right-hand side of the road is frequently obstructed at a critical time by such a thing as a truck ahead, and in that case the rear indication of the sign on the left may be in view. In the situation of a dark train across the road, the rear indication provides two possible aids in detecting its presence early. A driver who knows the situation may readily conclude that if he sees only the sign on his right, something is between him and the sign on the left, the latter sign being on the far side of the tracks. On a right angle crossing moreover, the rear reflector buttons on the far sign will flash intermittently between railroad cars as a dark train is passing over the crossing. This sign is made with a 50° angle between blades, instead of a 90° angle as often employed in reflector signs. The reason is that the 90° sign is regarded as standard for use in connection with signals, and at night the driver should be apprised of the fact that he is approaching a fixed sign, not a signal.

Driver's obedience to signals.

Passing now to the more important crossings protected by automatic signals or other visual protection, it may be interesting to review some studies made with a view to determining how effective such signals are, without special enforcement, in restraining drivers from going upon the crossing when a train is actually approaching.

Studies were made at a crossing at South Grand avenue with the Alton, in Springfield, at intervals from March, 1936, until December, 1936. Five series of observations were conducted, each involving a record of the highway traffic during the passage of 67 trains over the crossing, a total of 335 trains.

The record shows the actions of the drivers of 1 688 highway vehicles who came up to the crossing while the flashing-light signals were giving warning

of the approach of a train. Observers were located in a gasoline station near the crossing. An observer would start a stop watch when the signal began to flash on the approach of a train, and, as each highway vehicle came to the crossing, there would be recorded on the chart the time of its arrival with reference to the starting of the signal and whether the car stopped and waited, stopped and passed over the crossing, slowed down and passed over, or passed over with neither stop nor slow-down. In plotting the field notes the charts were reversed, that is, the time of arrival and the actions of the drivers were recorded with reference to the time of arrival of the train. Classifying with the « safe » or stop-and-stay drivers, those who arrived within three seconds or less after the signals began flashing, the figures are as shown in Table I.

TABLE I.

	Number.	Per cent.
Total cars	1 688	100.0
Stop and stay	1 422	84.2
Slow and pass	59	3.5
Stop and pass	72	4.3
Pass	135	8.0

The drivers apparently were very much influenced by the actual proximity of the train when they arrived at the crossing. Table II shows separately the actions of the drivers whose cars arrived at the crossing in each five-second interval from the time of passage of the train back to 20 sec. prior thereto, and also as a group, all those who arrived more than 20 sec. prior to the train.

Only 51 % of those who arrived 20 sec. or more prior to the arrival of the train, stopped and waited for the train, although the signal was showing a danger indication. The percentage of « stop and stay » drivers, however, increased progressively in each of the

TABLE II.
Actions of drivers, analyzed by 5-second intervals.

<i>Interval 0 to 5 seconds prior to arrival of trains.</i>	Num-ber.	Per-cent.
Total cars arrived in that inter-val.	428	100.0
Stop and stay	421	98.4
Slow and pass	1	0.2
Stop and pass	0	0.0
Pass	6	1.4
<i>Interval 5 1/2 to 10 seconds prior to arrival of trains.</i>		
Total cars arrived in that inter-val.	492	100.0
Stop and stay	455	92.5
Slow and pass.	7	1.4
Stop and pass	6	1.2
Pass	24	4.9
<i>Interval 10 1/2 to 15 seconds prior to arrival of trains.</i>		
Total cars arrived in that inter-val.	378	100.0
Stop and stay	321	84.9
Slow and pass	10	2.6
Stop and pass	12	3.2
Pass	35	9.3
<i>Interval 15 1/2 to 20 seconds prior to arrival of trains.</i>		
Total cars arrived in that inter-val.	190	100.0
Stop and stay	123	64.9
Slow and pass	9	4.7
Stop and pass	24	12.6
Pass	34	17.8
<i>Interval 20 1/2 seconds or more prior to arrival of trains.</i>		
Total cars arrived in that inter-val.	200	100.0
Stop and stay	102	51.0
Slow and pass	32	16.0
Stop and pass	30	15.0
Pass	36	18.0

succeeding five-second intervals up to the arrival of the train at the crossing, these figures being 64.9, 84.9, 92.5 and 98.4 %, respectively. Bearing in mind

that the signal was flashing and commanded a stop just as much in one of these intervals as in another, it is obvious that a large number of the drivers were being guided by their estimate of their chances of getting over the crossing in advance of the train, rather than by the command of the crossing signal. The signal, therefore, seems to be regarded by a large percentage of the drivers as merely conveying information, and not as a mandatory requirement to stop. In this connection, the Illinois statutes require a driver, under penalties, to stop when such a signal is giving a warning and not to proceed until it is safe to do so.

Signals not self-enforcing.

I emphasize that, at least insofar as this group of drivers may be regarded as representative, the signals at a railroad crossing do not appear to be self-enforcing, that is, the mere information of the approach of a train given by the signal, coupled with the supposed common sense of the drivers, is not sufficient to deter a considerable number of drivers from taking a chance. The danger of being killed or injured in a crossing crash does not seem to be of itself a sufficient deterrent.

Table III shows a combination of the two five-second intervals immediately prior to the passage of the train, in other words, the actions of all of the drivers who arrived at the crossing while the

TABLE III.
Actions of drivers arriving with train 10 seconds or less away.

	Num-ber.	Per-cent.
Total cars arrived in interval	920	100.0
Stop and stay	876	95.1
Slow and pass	8	0.9
Stop and pass	6	0.7
Pass	30	3.3

train was, in time, 10 sec. or less away. Clearly the hazard at such a time is very real, but notwithstanding that the train was actually so close, about five per cent still elected to take a chance. Of these, 83 % passed over the crossing without a stop or without apparent slow-down. More remarkable, however, was the mental attitude of the six drivers who, in such a situation, stopped their cars and then actually started again and passed over the crossing.

Referring back to Table II with respect to the five seconds prior to the passage of the train, a period in which there certainly can be no question of the great imminence of the danger, almost 90 % of the drivers still chose to take a chance. That means that approximately two vehicles out of each 100 are operated by drivers who appear to be willing to pass over a grade crossing in the face of a warning signal and five seconds or less ahead of the approaching train. This percentage of what we may call undoubtedly unsafe drivers is more than sufficient to account for all of the crossing accidents.

If this study reflects anything like representative conditions, we cannot rely upon a considerable percentage (fortunately a minority) of the automobile drivers controlling their vehicles safety at railroad crossings upon the giving of a merely informational warning. It is obvious that if our crossing signals are to protect the crossings efficiently, there must be some compulsion or some deterrent to crossing in the face of a danger indication, other than the hazard of the approaching train itself.

Let me repeat that this apparent readiness to incur an unwarranted hazard is not the private affair of the minority who show that readiness. Every driver who takes such a chance imperils the train crew and passengers, other users of the highway who may be close to the point of possible impact, as well as

other occupants, if any, of his own car. In a public safety study we cannot dismiss it, with a shrug of the shoulder, as a foolish act which carries its own penalty. The penalty too often falls upon others. It is a matter of public safety, not of private or personal behavior. These then, the reaction of the highway user to a warning of danger, and the problems of bringing about in some effective manner a compulsory observance and compliance, seem to be the chief factors from the human side in making crossing protective systems more effective and reducing the number of crossing accidents.

Human factors of protection.

Let us examine our protective systems from the mechanical viewpoint, and with some regard to co-ordination with human factors. All of our protective systems depend upon the perception of the eye or the ear of drivers of vehicles. Even the so-called firm barrier types (of which we have none in Illinois) which attempt to stop a vehicle physically, actually depend upon the eye and ear to prevent accidents, at the barrier if not at the train. There is, however, this natural classification that, in some types, the warning may be either disregarded or overlooked and the driver pass over the crossing without having the warning brought home to him, while in others he may not pass over the crossing without either breaking or driving around a barrier arm which wholly or partly obstructs his path. These, for convenience, we may call the visual and audible types on the one hand, and the barrier types on the other.

The visual and audible types include : (1) Fixed signs; (2) flashing-light signals; (3) wig-wag signals; (4) crossing watchmen; (5) flood-lighting, and (6) the locomotive whistle and bell. The only barrier types in general use involve the use of some sort of a gate,

either manually-operated or automatic.

It is a mistake to assume that either one of these general types is necessarily superior to the other. Crossing protective systems are in a sense, tailor-made; that is, while certain standards of aspect and mechanism are used, the system of control, as well as the type of protection chosen, must be adaptable for the particular conditions that prevail at each crossing. For example, the automatic flashing-light signal is probably at a distinct advantage, compared with barrier types, in the certainty of its operation, because the signal has practically no moving parts. I know of no record of an accident, in this state, where such a signal, of the present standard design, failed to operate when it should have operated. Thus, over automatic barrier types it presents the advantage of mechanical and electrical simplicity, and over manually-operated barrier types, the advantage of eliminating human failure in operation, a most important point. On the other hand, the reckless or drunken driver can pass without penalty, whereas a gate would probably break his headlights or windshield. Moreover, a properly lighted barrier is much less likely to be overlooked, and certainly the barrier type is more effective in the two-train situation. Other points may be mentioned, but this will indicate that as between these two general types, it is not a one-sided question. In Illinois the trend for several years has been strongly toward the flashing-light signal as the predominant type. Of late, however, there is an increased tendency to make use of the improved barrier types in situations where they are suitable.

So-called « false indications », that is the operation of the signal when no train is on or about to occupy the crossing, are undesirable, but to some extent cannot reasonably be avoided. The statute states the proper rule of conduct in such cases — the driver

shall stop and shall not proceed until it is safe to do so. In other words, signal should act in that case much as a stop sign at an entrance to a third street. It commands a stop, but has stopped, the driver, if he ascertains the way to be clear, may proceed. Unfortunately, people are rather prone to assume too hastily that any train engine in the vicinity is causing signals to work, and fail either to stop or to ascertain that the way is clear.

This suggests one of the situations in which many accidents do happen — these types of signals, namely, the two-train situation. The signal does give a warning of the second train by continued operation after the first train has passed, but that does not seem very effective. The improved types of visual and audible warning devices carried by the newer locomotives, are crossing protective equipment, and it may be that there is a practical field for improvement in the further study of these signals, especially in relation to human reaction.

Crossing watchmen.

Improvement in efficiency is needed in the use of crossing watchmen, which is a form of visual and audible protection. The advantage of this type of protection is in its simplicity, the ease with which watchmen can be shifted about and can be used in part-time service. The watchman, however, can be in but one place at a time, he can guard but one side of the crossing when it is on the crossing, not an object of high visibility, mingled in traffic, and his hand does not compare in power and efficiency with the lighting provided by modern signals. Often he performs his duties with considerable danger to himself; in fact, there have been several casualties to watchmen on duty.

Some progress has been made in adopting a suitable reflector type sig-

will soon be installed at all crossings in this state where part-time watchman protection is maintained. These signs display prominently the words « Watchman Off Duty » when the man is off, and conceal that message when he is on duty. A similar sign is provided for crossings where gates are operated part time, this reading « Gates Not Working ». A type of visual protection which seems to be very effective for some special situations is directional flood-lighting. This is not to be confused with open lights which produce a glare in the eyes of both highway users and locomotive enginemen.

Consideration of gates.

Leaving the purely visual and audible types, let us consider briefly the barrier type or the various forms of gates, manually-operated or automatic. The strongest points of this type of protection seem to be these : First, it places its warning directly in the path of oncoming traffic, and if properly lighted and operated, it is far less likely to be overlooked than a signal to the side of the road. Second, it carries some compulsion. A driver, unless he stops, must crash it or drive around it. In the latter case he necessarily slows down and re-

cognizes the warning, in the former case he risks damage to his car. Third, it holds back traffic in the two-train situation.

The disadvantages are, mainly : First, there are more mechanical parts and possibility of mechanical failure. Second, the element of human failure, of gate operators, or of irregular operation is always present in the manually-operated types. Third, in the automatic types, the control circuits become more elaborate and complicated, for many situations at least. This is mainly because the gate cannot, like the signal, function reasonably as a « stop and proceed » indication, and the operation of the gate must not unduly obstruct the highway.

One recent trend, in both manual and automatic types, is the use of the short arm, that is, an arm which only obstructs the traffic lanes on the right-hand side of the center of the highway and does not obstruct those on the left. Many of these are in use, and experience seems to show that there are practically no accidents caused by cars driving around the ends of the arms. On the other hand, the danger of trapping cars between gates is eliminated and with this comes another important improvement, more regular and timely operation of the arms. No doubt there are places where full coverage of the street is advantageous, but there is a tendency to make more use of the short arm, for vehicles at least. A type of short arm automatic gate combined with flashing-light signals seems to be giving good service in this state. The advantage of combining the signal with the gate is that if the arm is broken, the crossing is still protected by the signals. It may be mentioned that the combination of flashing-light signals with a gate arm is not, as I understand it, a patentable combination and any manufacturer can make use of this combination of standard units.



Automatically controlled short-arm gate in addition to flashing-light signals.

We may sum up the situation, therefore, with reference to the present status of the barrier type protection by saying that there seems to be an increasing tendency to make more use of the more up-to-date forms of this protection, with emphasis on the short arm gate either manually or automatically operated, and upon the combined use of a barrier arm with flashing-light signals. The more extended use of automatic gates, however, will probably entail the development and use of selective control circuits, that is, those which distinguish between fast and slow trains, as well as provision for switching and other conditions which might cause lengthy obstruction of the highway. The excellent record of the automatic gates is such as to warrant further trial of these types with a view to developing their proper place in the general scheme of crossing protection.

The pedestrian problem.

The pedestrian accidents at railroad crossings are far less numerous than those involving vehicles. For example, in the year 1936, out of a total of 721 persons killed or injured at grade crossings in Illinois, only 46 were pedestrians. One of the chief points of hazard for pedestrians is suburban stops, where the tendency of commuters is to swarm around the rear end or the forward end of the train, and get in the way of another train. This seems to be actually more of a police problem than an engineering problem. Occasionally a pedestrian ducks under the lowered gate and it is difficult to suggest anything more than a police solution for this situation. Several pedestrian fatalities have occurred, apparently as the result of pre-occupation of the victim, in that he walked into the path of a train despite the warning of a signal or flagman. Here the sidewalk gate arm certainly appears to have merit.

In some instances the protection of children is presented as the chief purpose of crossing protective systems. This attitude finds very little support in the cold facts, so far as the child pedestrian is concerned. An accident to a child is peculiarly regrettable and usually arouses a shocked public sentiment, nevertheless, as a statistical fact, children as pedestrians are rarely struck by railroad trains. This, unfortunately, does not apply to a child on a bicycle. A bicyclist should not be classed as a pedestrian for this purpose, as is sometimes done. If a suggestion is to be made concerning the special safety of children, it would be to concentrate upon the child bicyclist. In this connection, also, it might be observed that an average crossing watchman is far more efficient in controlling children than is sometimes assumed to be.

Summary of conclusions.

To summarize our entire discussion, therefore, let us observe that accidents at railroad crossings result from either human or mechanical factors, or a combination of the two, but where mechanical factors are involved, they nearly always also involve human factors. In a study of the situation, therefore, it is necessary to place considerable emphasis upon the human factors. The distribution of accidents is such that we have a real problem of protection at the minor or little-used crossings in some better way, either by traffic control or mechanical means, and, while the distribution of accidents in the aggregate suggests that a large part of our accidents, the problem of their treatment has not been solved. At the crossings specially protected, the human factor is of great importance since it appears that mere knowledge of danger from the train itself is not sufficient incentive or compulsion to restrain a considerable number of highway users from incurring a hazardous hazard.

The visual and audible types of protection are highly developed and of great mechanical reliability and if the human element could be controlled better, they would be of much greater efficiency. The barrier types of protection have important advantages in that, among other things, they introduce a certain degree of automatic compulsion, but on the other hand, their use often entails drawbacks in the way of introducing human factors of failure of apparatus or operation, additional risk of mechanical fail-

ure and complication of control systems. The problem of the child pedestrian is one that is usually greatly over-estimated, at least from a numerical standpoint, but the child bicyclist is a problem of about the same sort as the drivers of vehicles in general. Rapid progress has been made in the last four or five years in the field of crossing protection but further progress is necessary before we can expect the same degree of safety at railroad crossings as we have in other phases of railroad operation.

The make-up of the trains in relation to the traffic density on different railway lines,

by P. KANDAUROFF, Engineer, Paris.

The amount of traffic varies a good deal from one railway line to another, especially in the highly civilised countries of Europe where the railway has practically reached its maximum development. Exact information on this subject is rarely published in the reports, and it is very difficult to obtain it ⁽¹⁾.

The annual statistics of the Swiss Federal Railways give very valuable information about the train-miles, axle-miles and gross tonnage ⁽²⁾ on the different lines of the system, sometimes even for certain special sections of important lines.

These statistics show that the traffic

varies much on the different lines. For example in 1936, on the Basle-Olten line 102 trains ran in the two directions between Pratteln and Sissech (13 km. = 8.1 miles), 63 of which were passenger trains of various kinds, while on the branch line from Le Day ⁽³⁾ to Brassau (21.8 km. = 13.5 miles) there were on the average only 8.5 trains a day, and practically no goods trains at all.

The following table shows, for the year 1936, the distribution of the train-miles, axle-miles and gross ton-miles for 95 % of the lines operated by the Swiss Federal Railways, with 97 % of all the trains :

Number of trains par day.	Length of lines.		Distance covered by the trains.		Axle-kilometres, thousands.		Gross tonne- kilometres.	
	km.	%.	km.	%.	Total.	%.	Total.	%.
Up to 10. . . .	40	1.4	154 314	0.4	1 061	0.1	8 439	0.
10 to 20	677	23.8	4 540 576	11.7	71 138	5.5	548 595	5.
20 to 30	485	17.1	4 798 331	12.4	105 979	8.2	853 140	7.
30 to 40	678	23.8	9 179 066	23.6	288 135	22.4	2 434 178	22.
40 to 50	380	13.4	7 101 549	18.2	261 281	20.3	2 195 260	20.
Over 50	582	20.5	13 115 052	33.7	559 608	43.5	4 852 114	45.
Together . .	2 842	100.0	38 888 888	100.0	1 287 274	100.0	10 891 726	100.

(1) Since the War about the only information of this kind published is that given in Tables III and IV of an article by Dr. BLUM : « Das Eisenbahnnetz Niedersachsens » (Archiv für Eisenbahnwesen, 1933).

(2) The gross tonne-kilometres given never include the weight of the locomotive.

(3) 4 km. (2.5 miles) from Vallorbe.

This table shows that the number of pairs of wheels and the gross weight increase with the number of trains. The result is that, with heavy traffic, not only the fixed plant but the trains themselves are more fully utilised. This is an extremely important point, as many operating costs vary in direct proportion to the number of trains, while the receipts are

only in proportion to the passenger-kilometres and gross tonne-kilometres.

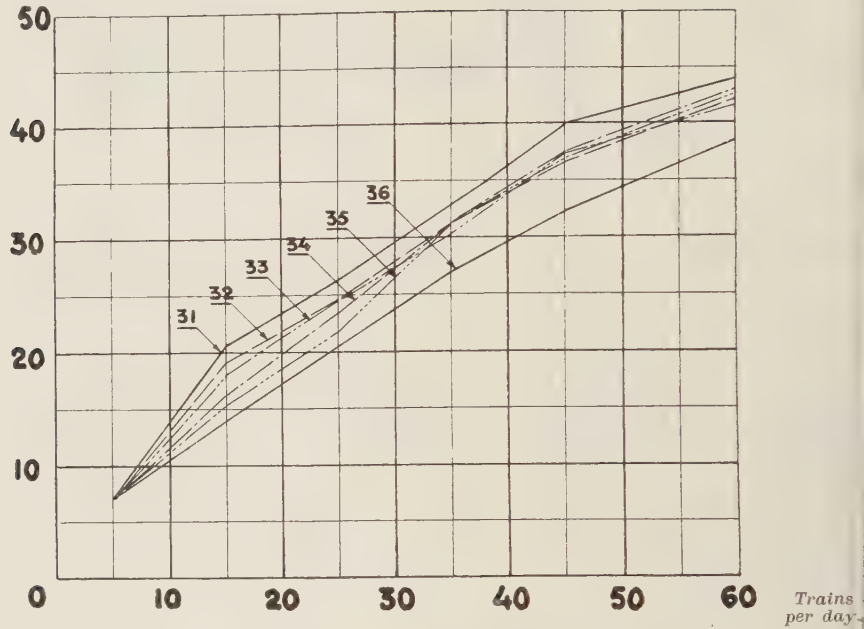
Another fact which should be noted is that the average number of pairs of wheels per train, and to a lesser extent, the gross weight per pair of wheels, increase very regularly with the number of trains, as is shown by the following table :

Average number of trains per day.	1931		1932		1933		1934		1935		1936	
	Axles per train.	Gross tonnes per axle.	Axles per train.	Gross tonnes per axle.	Axles per train.	Gross tonnes per axle.	Axles per train.	Gross tonnes per axle.	Axles per train.	Gross tonnes per axle.	Axles per train.	Gross tonnes per axle.
Up to 10 .	6.7	6.35	7.0	7.79	7.1	7.82	7.0	7.54	6.9	7.96	6.9	7.91
10 to 20 .	20.6	7.33	19.2	7.41	18.3	7.42	16.8	7.49	15.7	7.70	14.1	7.91
20 to 30 .	26.4	80.1	24.6	8.09	24.5	8.11	23.5	8.31	22.1	8.05	20.4	7.66
30 to 40 .	32.8	8.17	31.6	8.39	30.6	8.34	30.9	8.36	31.1	8.47	27.1	8.54
40 to 50 .	39.7	8.17	37.5	8.25	37.4	8.38	37.6	8.46	36.8	8.40	32.5	8.47
Over 50 .	44.0	8.44	42.1	8.49	42.0	8.56	43.2	8.60	42.7	8.66	38.7	8.53
Average number for all the lines.	35.3	8.41	33.5	8.30	33.0	8.34	33.5	8.43	33.1	8.46	29.8	8.33

The following graph shows still more clearly the regularity with which the increase in the number of pairs of wheels follows the increase in the number of trains. The form of the curve varied only slightly between 1931 and 1936. It may be noted, however, that the number of pairs of wheels per train falls progressively on all the lines, owing to the increasing competition from other means of transport. This competition in fact forces the railway companies to increase continually the number of trains,

particularly passenger trains, whilst reducing the number of seats per train. The ruling gradients of the different lines only have a secondary influence on the number of pairs of wheels per train. We might quote as an example the Gothard line, one of the most characteristic mountain lines in the world, whereon in 1936 the average train consisted of 38.7 pairs of wheels, whereas on the Geneva-Lausanne line, which is entirely on the level, the average was 30.5. On the other hand, the average composition of the

*Average number of
axes per train.*



trains on the different lines varies according to the kind of traffic. In general, the number of pairs of wheels per train

is higher on the lines where the proportion of goods trains is highest.

[621. 43 (.75) & 623. 232 (.75)]

The new diesel-electric streamliners « City of Los Angeles » and « City of San Francisco », for Pacific Coast service.

(From *The Railway Age*.)



Union Pacific 3-unit 5 400-H.P., diesel-electric locomotive built by the
Electro-Motive Corporation.

The original diesel-driven, articulated, aluminium alloy streamliners « City of Los Angeles » and « City of San Francisco » were placed in service on a 3/4-hour schedule between Chicago and the Pacific Coast over the lines of the Chicago & North Western, Union Pacific and Southern Pacific, in the early summer of 1936. They comprised a double-unit locomotive and nine trailing cars per train. The locomotives of these original trains were built jointly by the Electro-Motive Corporation and the Pullman-Standard Car Manufacturing Company and the car-body units, constructed for the most part of strong aluminum

alloys, were built by the latter company. The immediate popularity of these trains and attendant increased traffic demands have now necessitated replacing them by complete new equipment, furnished by the same builders, which includes two 5 400-H.P., 3-unit locomotives and 14 car-body units per train, the largest, most powerful and finest-appointed streamline trains yet constructed.

The new City of Los Angeles was placed in service on December 27, 1937, and the new City of San Francisco on January 2, 1938, these trains being of essentially the same construction except

for slight differences in available accommodations, overall length, weight and passenger capacity. Each 3-unit locomotive is approximately 209 ft. long and weighs about 877 000 lb. The new City of Los Angeles cars include a baggage-auxiliary-engine-dormitory car, two chair cars, a diner-kitchen car, a dining car, a dormitory-club car, seven sleeping cars and an observation lounge, these cars being articulated only to the extent shown in the table.

The new City of San Francisco cars include the same types of equipment except that there is one less chair car and one more sleeper. The total length of cars (without locomotive units) in the City of Los Angeles is practically 1 057 1/2 ft., the passenger capacity 245, and, owing to lightweight construction, the total light car weight on rails is only 1 581 200 lb. The City of San Francisco cars have an aggregate length of about 1 082 1/2 ft., passenger capacity of 222 and total light weight on rail of 1 622 700 lb.

Other important differences in the two trains are as follows: On the City of Los Angeles, the electric power transmission equipment, including the auxiliary power plant generators, is General Electric; air brake equipment is of the AHSC type, furnished by the New York Air Brake Company. On the City of San Francisco, Westinghouse electric power transmission equipment is installed on the locomotive; auxiliary power plant generators are General Electric, and AHSC brakes are supplied by the Westinghouse Air Brake Company. Timken roller bearings are installed on the center axles of six-wheel trucks on both trains, all other axles being equipped with SKF roller bearings.

The locomotives.

The diesel-electric locomotives for the new City of Los Angeles, and its twin, were built by the Electro-Motive Corpor-

ation, La Grange, Ill., a subsidiary of General Motors. The power plants comprise G. M. diesel engines, with complete electric power transmission equipment for the first train furnished by the General Electric Company and for the second train by the Westinghouse Electric & Manufacturing Company. The City of Los Angeles is owned jointly by the Union Pacific and the Chicago & North Western, and the City of San Francisco by the Union Pacific, the Chicago & North Western and the Southern Pacific.

Each of these 5 400-h.p. locomotives is composed of three 1 800-h.p. units coupled for multiple-unit operation from a single control station in the operating cab of the leading units. The motive power for the 1 800-h.p. units is identical and comprises two 900-h.p. diesel electric power plants, controlled simultaneously from the main locomotive throttle. The three units per locomotive are identified as A, B and B, the two latter units being of equivalent construction and interchangeable.

The first car in the train, or the one coupled next to the locomotive, is an auxiliary-baggage-dormitory car. This car carries 1 200-h.p. of auxiliary power-generating equipment for the operation of the train auxiliaries, such as air conditioning, car lighting, telephone, radio, etc. This power is derived from two G. M. 600-h.p. diesel-electric units operating in multiple to supply 220-volt 3-phase, 60-cycle alternating current. The a.c. power supply is supplemented by a 710-amp.-hr. storage battery of cells, at 64 volts, which is used for auxiliary apparatus-control circuits, and emergency lighting in the event of failure of both auxiliary power plants. Battery charging is accomplished by a small 12-kw. motor-generator set driven by power from the a.c. supply lines.

Principal features of the construction

The locomotive body units comprise for the most part welded steel construction.

on designed to meet Railway Mail Service specifications for the class of equipment requiring 400 000 lb. buff. The outside finish, made of plywood panels covered with galvaneel steel, is applied by means of battens riveted to the framing structure. Not being subject to load stresses this finish, therefore, remains smooth and free from buckling.

The total weight of the locomotive with a full supply of fuel, water and sand, approximates 877 000 lb. This weight is 298 000 lb. for the A unit and 59 500 lb. each for the two B units. Each of these weights is divided between the two six-wheel trucks, and further proportioned to the two driving, and single idle axle of each truck. This distribution provides an average wheel loading at the rail of 23 730 lb. for the leading axles and 24 690 lb. for the drivers. All truck assemblies are interchangeable. They weigh, including motors, approximately 50 000 lb., and have a 14 ft 1 in. rigid wheel base. The truck frame and swing bolster are of alloy steel, while the spring planks are of rain-relieved welded construction. High-molybdenum, low-carbon, rolled-steel wheels, 36 in. in diameter, are mounted on three A.T.E.A. E-11-X axles running 6-in. by 11-in. journals. The maximum journal load is 22 650 lb., which is carried on special SKF double row bearings.

Good riding qualities and stability in negotiating curves at high speeds have been obtained by an ingenious treatment of load suspension. The truck frame is supported at four points by twin-group coil springs of silico-manganese steel, which ride on four equalizers carried by the journals. The bolster casting is supported at each corner by a pair of chrome-vanadium elliptic springs. These springs ride on two welded steel spring links, which in turn are carried by hanging hangers pivoted from the outside of the truck frame. Lateral oscillations of the bolster are dampened by four hy-

draulic shock absorbers which also act to ease the body load against the truck frame when entering or leaving curves.

Each truck has two traction motors geared directly to the outer axles, and is truck mounted in the usual manner between the driven axles and the truck transoms. The center axle is an idler and is necessary for load-carrying purposes only. Clean, dry air is forced to the motors by blowers located in the car body directly above each center plate. This air is directed to the motors through cored openings in the bolster and body center plates, and from the bolster to the hollow truck transoms through matched openings in each. The passages between the swing bolster and transom sections are sealed by a Fabreeka gasket and steel slide-plate arrangement. From the transom, the air passes to the motors through flexible rubber ducts permanently fastened to the motor and transom openings.

Independent operation of locomotive units.

Truck assemblies are equipped with American Steel Foundry's clasp brakes actuated by four brake cylinders per truck. Each cylinder is fitted with a manual slack adjuster. Automatic and manual sanding is provided at the leading wheels of each truck of the coupled locomotive.

Although the second and third units of the locomotive are equipped for independent operation in yard movements such as turntable maneuvers, the locomotive main throttle is located at the control station in the operator's cab at the front end of the leading unit. The streamlined contour of the head end follows closely the familiar original Union Pacific design to provide maximum safety and visibility for the operator and also to reduce wind resistance at high speeds.

Seated in a deeply upholstered adjustable seat, the operator has a clear vision

of both sides of the track ahead through slanting automotive style windshields of 9/16-in. safety glass, equipped with special windshield wipers and hot-air defroster arrangements. The cab side windows are likewise of the automotive type with no-draft ventilators and adjustable side windows, also of safety glass.

The operator's instrument panel provides for indirect illumination of an electric speedometer, and the customary air gages which indicate brake and automatic-train-control functions. At the right of these instruments is the wheel-slip indicator, which flashes a warning light when any pair of locomotive driving wheels slips due to poor track conditions. Automatic train control signal lights are mounted centrally in the cab directly below the windshields. A telephone hand set is within arm's reach of the operator by which the conductor may give verbal instructions as a supplement to the usual engineer's air signal. A signal system is also furnished for exchange of signals between the operator and train mail crew.

The cab is provided with two additional seats located centrally and on the left of the compartment. The left position is also equipped with a windshield wiper, defrosting device, and no-draft ventilation. All cab positions are protected from sun glare by adjustable sun visors.

Locomotive movements are controlled by the use of only three levers; the locomotive main throttle, reverse lever, and air-brake handle. With the engines idling and the reverse lever in running position, any movement of the locomotive throttle is relayed electrically through four control trunk wires to each power plant of the locomotive. These telegraphic impulses are received by an electro-pneumatic device which actuates the local engine-speed governor lever to increase or decrease engine speed and

thus control the individual power-plant output.

At the head of each engine there what is termed a local control station from which the attendant may check operating condition of each individual power plant. At this station are located the fuel and lubricating-oil gages, r.p.m. indicator, 12-point exhaust pyrometer, engine water thermometer, the engine start-and-stop buttons, and an isolation switch having two positions, on and off. Moving the switch handle to the off position opens all electrical control circuits to that power plant and reduces engine speed to idling, irrespective of the operation of the remaining power plants. Returning the switch to the on position closes the control circuits, the engine immediately responds to power demand being called for by the operator or position of the locomotive throttle.

In addition to the indicating instruments at each control station, the locomotive is equipped with a trunk alarm system, whereby an improper engine condition is brought to the attention of the attendant by an audible as well as visual alarm. This system includes engine water temperature and pressure switches, an 8-in. electric gong, and four illuminated annunciator signals in each locomotive unit and the auxiliary power plant compartment. The annunciator boxes have three lenses of different colors corresponding to high engine, low oil pressure, and boiler failure. The alarm gong rings with the illumination of any of the three signals and continues until the failure has been isolated and acknowledged by placing the isolation switch handle in off position. This same gong is utilized as a cautional for the attendant by use of a button in the operator's cab.

Essential units of the power plant

The essential units of each power plant comprise in general:

ne with its attendant cooling, fuel and lubricating oil systems, power generator and exciter, battery-charging generator, and the necessary contactors, switches and fuses for the control of electrical circuits. In addition to two such power equipments, each locomotive unit carries 200 gallons of fuel and 1100 gallons of water for the train-heating steam boiler.

The G. M. diesel engines are of the four-cycle, V-type, with 12 cylinders, having 8-in. bore and 10-in. stroke, seven-bearing crankshaft, drop-forged connecting rods, needle-bearing wrist pins, aluminum pistons, lubricating-oil and water pumps, and deliver 900 H.P. each at 750 r.p.m.

The main generators are 600-volt, d.c. with differential voltage control through belt-driven exciter-auxiliary generator sets, and are used to supply power for the two 450-H.P. traction motors mounted in each truck immediately below each power plant. The generators also act as engine starters when receiving energy from the locomotive batteries through separate contactors supplied for this purpose.

The engine-cooling system consists of 100 sq. ft. of water-cooling radiators per engine, hung from the removable roof brackets, through which openings the engines and generators are lowered into the car body. Air for radiator cooling is taken in through grilled openings in the sides of the car body, and forced out through the radiator assemblies by three 14-in. propeller type fans which are belt driven from the main engines. Automatic and manually operated shutter arrangements are provided ahead of each engine group for control of engine water temperature during service or main-line operations. With the stopping of the engines, the shutters close automatically and all radiator water drains into the main water storage tanks.

Each engine is served by an indepen-

dent fuel system consisting of a motor-driven tandem pump arrangement, necessary filters, pressure relief valves, and I.C.C. approved fuel gages.

Steam heat is furnished by a Vapor-Clarkson flash-type steam generator, having a capacity in excess of 2200 lb. evaporation per hour at 225 lb. steam pressure. Feedwater pumps, flame control, and train-line pressure regulation is fully automatic as adjusted by a single hand rheostat. The steam train-line extends the full length of each locomotive unit to provide steam for heating the operator's cab while in service, and also to warm the engine water systems during the maintenance or lay-over periods.

Air-compressor equipment for the 5400-H.P. locomotive constitutes six two-stage water-cooled compressors of 79.4 cu. ft. displacement at 750 r.p.m. They are belt-driven from a shaft extension of each main generator. The compressed air is cooled by 42 ft. of fin copper tubing and stored in two air-cooled reservoirs, 24 1/2 in. by 66 in. having a combined capacity of 56500 cu. in.

Locomotive air brake equipment is of the AHSC high-speed control type, that used on the City of Los Angeles being furnished by the New York Air Brake Company and that on the City of San Francisco by the Westinghouse Air Brake Company; the majority of the apparatus is piped on a single panel mounted in the hood compartment in front of the cab. Automatic train control and cab signal equipment, of the U. S. & S. continuous type, is likewise assembled on panels and housed in the front hood. Both air-brake and train control equipments are arranged to actuate a pneumatic switch which reduces all engines to idling, in the event of an emergency brake application or train-control penalty stop.

The locomotive headlight is equipped with a 12-volt, 360-watt pre-focused bulb which receives its energy from a special

d.c. driven, a.c. output, motor-generator set. This generator delivers 32-volt alternating current for the illumination of the vertical-beam headlight distinctive to all Union Pacific diesel locomotives. Through a transformer this energy is reduced to 12 volts for the locomotive horizontal beam light. Control switches are arranged to transfer the headlight power supply from the motor-generator to locomotive storage battery in cases of emergency.

The locomotive storage battery installed in each unit is a 25-plate 32-cell Exide Ironclad. On the A unit it is located in the hood compartment at the front end. On the B units it occupies a similar location but is grouped in two tiers in the center of a platform to provide aisle space on either side.

General arrangement of the cars.

The general arrangement of cars in the new City of Los Angeles is indicated in the table by the numbers 1 to 14 beginning with the auxiliary-power car and ending with the observation lounge. In addition to auxiliary power plant equipment, the first car back of the three-unit locomotive has a 24-ft. compartment for baggage in one end and a 27-ft. dormitory in the other end for the accommodation of an 18-man crew. Next come the chair cars, two on the City of Los Angeles and one on the City of San Francisco. General and individual lighting, individual adjustable seats in rust-colored upholstery, cream-colored ceilings and blue shades on the floor coverings make a harmonious decorative effect.

General dimensions and weights of car equipment for the New City of Los Angeles.

Car number.	Type of car (*).	Car length, ft. in.	Seating capacity.	Light body weight, lb.	Lading weight, lb.
1	Baggage-auxiliary-engine-dormitory . . .	84 6	18 Δ	140 700	22 240
†2	Chair (women's)	72	52	65 620	10 300
†3	Chair (men's)	72	52	64 830	10 300
†4	Diner-kitchen	72	32	74 295	14 850
†5	Dining car	72	72	65 970	16 600
6	Dormitory-club	84 6	35	77 310	10 300
†7	Sleeper, 4 compartment, 3 drawing room .	72	17	67 515	5 500
†8	Sleeper, 12 section, open	72	24	66 670	6 500
†9	Sleeper, 4 compartment, 3 drawing room .	72	17	69 815	5 500
†10	Sleeper, 14 roomette.	72	15	71 040	5 100
†11	Sleeper, 11 bedrooms.	72	22	71 875	6 400
†12	Sleeper, 12 section, enclosed	72	24	69 420	6 500
13	Sleeper, 5 bedrooms, 12 duplex single rooms	84 6	22	82 240	6 300
14	Observation-lounge	83 11 1/2	36	71 930	9 500

Total length (14 cars), 1 057 ft. 5 1/2 in.

Total light center plate load (14 cars), 1 059 200 lb.

Total car lading (incl. passengers), 136 000 lb.

Total truck weight (23 trucks), 522 000 lb.

Total light car weight on rails, 1 581 200 lb.

Total maximum car weight on rails (incl. passengers), 1 717 200 lb.

* Essentially the same as those of the new City of San Francisco.

† Articulated.

Δ Crew.



Non-articulated connection between cars.
Steps open and closed.

Behind the chair cars is the kitchen-car, half of which is occupied by the kitchen that serves it and the main diner, just behind. Blue is the dominant note in the former, used in carpeting and draperies, but the chairs are bright red, and tan pigskin-finished wainscotings aid in effectiveness. Copper and blue coloring is featured in the main diner, both in the oval-backed carpeting, Venetian blinds, window drapes and the ceiling. The ceiling is light yellow and so is the Irish napery. The wainscotings are of cork and the panels are mirrors of blue tinge.

Authentic late-Victorian red is the predominant color impression in the Little

Nugget, or dormitory-club car, of the City of Los Angeles. The ceiling is of star-studded blue. An old-fashioned bar is at one end of the lounge, and on the walls are photographs of stage favorites of that day. The interior design of the Little Nugget is by Walt Kuhn, noted American artist, executed by Mandel Bros. The corresponding car on the City of San Francisco is a contrast, being of modern design and less colorful decoration, but notable for the many conveniences and comforts demanded by modern travelers.

Seven Pullmans on the City of Los Angeles and eight on the City of San Francisco are owned and operated by the Pullman Company. They furnish all types of accommodations, including open and enclosed sections, roomettes, bedrooms, Duplex rooms, compartments and drawing rooms. The beauty of the color schemes attracts general attention. For instance, the four-compartment three-drawing room cars are in tan and apricot and have seat coverings in red, green and brown. The carpets are of complementary green and brown, and the shades carry out the same effect in horizontal pattern. Both compartments and drawing rooms are of the new type with folding lounge chairs for day use, in addition to lounge seats.

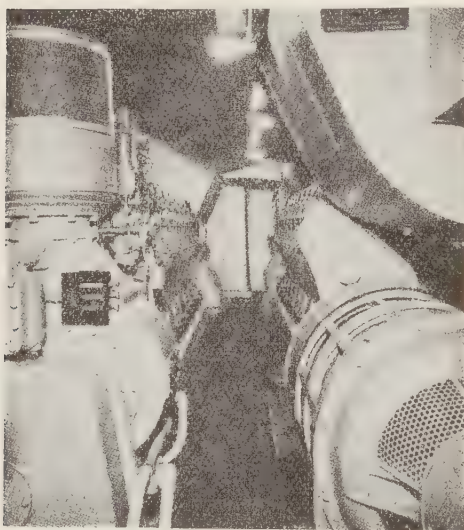
The bedroom cars have rooms in both tan and blue. The former have raisin-colored carpets, jade green upholstery and brown and tan window shades, while the blue rooms have the same car-



One of the six-wheel trucks used at articulated body connections.



Type of four-wheel truck used where light car weight permits.



Dual electro-motive power plants in the baggage-auxiliary-engine-dormitory car.

peting but the seat coverings are rust-colored and the window shades blue and tan. One of these cars is of the Duplex type, with five double bedrooms and 12 single rooms, half of which are « upstairs ». The other car has 11 bedrooms, many of which are connecting and furnish plenty of space for family party use.

The roomette car, the latest Pullman innovation, has 13 rooms, each a little larger than a section, with a bed that

folds into one wall, and individual toilet facilities and heat and light control. The rooms are in shades of blue and green with dark brown carpeting, rust-colored upholstery and rust and tan window shades.

The open section sleepers have green walls and ceiling, with metal finish in copper. Rust-colored seat coverings and raisin-colored carpets, and rust and tan striped window shades add to the attractiveness. The City of Los Angeles carries an enclosed-section sleeper with treatment in yellow and blue. The walls and ceiling are in yellow shades, the upholstery is brown, the carpets dark blue and the window shades coral.

The observation lounge is the last car and resembles a large, finely-appointed living room of simple, effective design. The walls are of light blue with a horizontal band of oriental wood entire around the car at window height. The ceiling is in light cream; the carpet a brown twist-weave; the draperies striped in blue, tan and rust; and the metal Venetian blinds, in the observation end of this car, are for the first time fitted to curved window frames. These blinds match the coverings of the lounge chairs which are built of satin finish aluminum.

Large auxiliary electric power consumption

The quantity of electrical equipment

provided on these trains is one of their outstanding features. In addition to 400 H.P. of diesel-electric motive-power equipment, each train is equipped with 600 kw. of auxiliary power equipment, supplying power for various features including the high-speed uniform retarding brake system; cab signal and automatic train stop equipment; air conditioning; electric overhead heating in addition to steam floor heating; separate telephones for the use of passengers and train crew; 32-volt d.c. and 110-volt, 60-cycle a.c. receptacles in all individual rooms; complete annunciator systems in the club, dining, observation and sleeping cars; 15-tube, 220-volt a. c. radio sets in the chair, diner, observation and lounge cars; radio receptacles in drawing rooms and compartments, with serial round and 110-volt a. c. connections for portable radios; and 32-volt a. c. and 110-volt a. c. lighting systems. In addition, a regular and an auxiliary 64-volt battery is provided for the control apparatus and as emergency train lighting standby.

The Electro-Motive power plant in the center compartment of the baggage-auxiliary-engine-dormitory car consists of two G. M. 450-H.P. diesel engines running at 720 r. p. m. and driving two direct-connected three-phase, 60-cycle, 220-volt E. generators, with exciters on the same shaft. The generators together are rated at 600 kw. at 80 % power factor. Manual synchronization is provided so that the generators may be run in parallel, as well as separately. Power from the generator bus is fed to circuit breakers which connect to four power lines A, B, C and D, throughout the train. The two three-phase train lines A and B, for cooling and heating requirements, consist of two 350 000 cm. cables in parallel for each conductor of each three-phase line. The two train lines C and D for lighting and miscellaneous power, consist of No. 3/0 cables. These power transmission lines make a total of twel-

ve 350 000 cm., and six No. 3/0 cables throughout the train.

This large amount of copper is necessary to hold the voltage drop down to a reasonable figure for a transmission distance of about 1 300 ft. The total voltage drop in each train line for the air conditioning load is from 2 % to 2 1/2 % and the total voltage drop in each train line for the lighting load is about 3 %.

Inter-car jumpers are of a special, positively latched, automatic pull-out type at coupled connections, and a bolted terminal type at articulated car connections. A control wire is run with all power jumpers, the disconnection or breaking of which trips the main train-line circuit breakers before arcing can occur at the parted jumper. Standby receptacles for yard service are provided on the auxiliary power car for all power train lines.

The cooling and heating electrical loads are balanced between trainlines A and B, and the lighting and appliance loads are balanced between trainlines C and D. Inasmuch as the greater portion of the electrical load on lines C and D is single phase, special care was taken to balance the loads on each phase. Where a single car load was of sufficient size, economically considered, three single-phase transformers were used to obtain a local balance; in articulated cars balance was designed for the pair as a unit, as far as practicable. On the whole, the cumulative totals of single phase loads, segregating lamp and motor (lagging current) loads, were kept nearly balanced, step by step, from the auxiliary power car to the observation car.

An idea of the electrical load on each of these trains can be gained from the fact that the lights alone reach a maximum of more than 7 kw. in one car. Based on data compiled for the City of San Francisco, the total connected load on lines C and D is about 76 kw. The

total connected cooling load on lines A and B is approximately 212 kw. The total demand on the generators, including losses in the transmission lines, for the summer load is about 305 kw. for cooling and lighting, and for the winter load about 516 kw. for heating and lighting.

Direct current power supply.

Regulated 64-volt dc. is supplied from an Exide MVAH-41, 710-amp.-hr. capacity, 32-cell storage battery installed underneath the auxiliary power car, through a No. 4/0 trainline to all control apparatus, emergency lighting, marker lamps and air brakes. This battery is charged through a 12-kw., 220-volt a.c. motor-generator set. An auxiliary 64-volt, Exide MVAH-11, 175-amp.-hr. capacity battery is provided in the observation car. This rear battery is on continuous trickle charge and is automatically charged at a 25-amp. rate through a full-wave, vacuum tube rectifier whenever its voltage falls below a pre-determined figure. The rear battery is automatically connected to the 64-volt d. c. train line upon the breaking of this line. The contactor for the above is also provided with electrical controls for opening or closing it by push buttons, and operation is restored automatically by reconnection of the train line, whatever the previous history of operation has been. Both batteries are provided with receptacles for charging from outside direct-current sources. The head-end battery motor-generator set is connected to a transfer switch which enables this charging set to be operated from 220-volt a. c. standby.

The 64-volt emergency lights are automatically turned on upon the failure of the a. c. in the lighting train line from any cause, and are cut off upon resumption of a. c. power. An additional No. 2/0 train line, terminating at the car ends in standard Gibbs receptacles, is provided so that the cars of this train



The Little Nugget dormitory-club car of the City of Los Angeles.

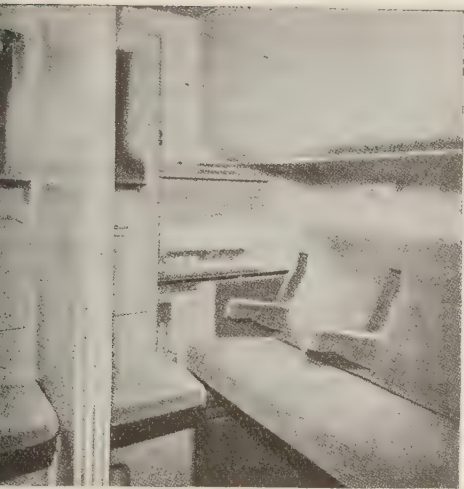
may be operated in steam trains with conventional 32-volt d. c. lighting. A transfer switch is installed in each car to connect selected 32-volt circuits to this train line. Two 16-wire train lines are provided for the necessary train apparatus control.

Features of the body construction. Trucks. — Brakes.

The main difference in construction



The dining compartment of the diner-kitchen car.



Lower single room
in one of the new duplex sleepers.

between the cars of the new City of Los Angeles and City of San Francisco and their predecessors is the provision of a slightly wider and higher cross section, straight car sides instead of tapered, and wider lounge room window openings.



Interior appointments
in the observation lounge car.

The side framing is of girder type construction, of aluminum alloy. End sills, bolsters and needle beams are of high-tensile steel, welded construction. All important castings subject to high stresses are of heat-treated alloy steel. Center sills, side sills, posts, columns, sheathing, roofs and all other framing are of aluminium alloy. The roof is of the round type. End framing incorporates an anti-telescoping construction.

The floor construction in the passenger-carrying cars is composed of a specially pressed aluminum sheet. In the railroad-owned cars, the top and bottom depressions are filled with cork strips on top of which is applied a 1-in. layer of cork base as a foundation for the top floor covering. In the Pullman cars a special cork mixture composition is used.

Floors, sides, ends and roofs are insulated with a mineral base insulating material. The baggage and auxiliary engine room windows are of the porthole type, glazed with shatter-proof glass. Elsewhere throughout the cars the sashes are of hermetically sealed dehydrated unit-type, the outer glass being 1/4-in. clear Crystalex plate, and the inner glass of clear-shatterproof. Translucent outer lights of glass are provided in toilets and bathrooms. All doors are of Plymetl construction.

For the entrance of passengers, folding-type steps and a trap door on each side of the single vestibule per car are provided; the steps are designed so that when in closed position the back lines up with the contour of the car shell. The gaps between cars are entirely closed, stretch rubber being used at the car sides and for the enclosure of the center passageway. Waughmat draft gears are used in combination with tight-lock couplers and yokes.

All six-wheel passenger-car trucks in these trains, also all four-wheel trucks on Pullman cars, are equipped with Commonwealth one-piece alloy cast-steel

frames, furnished by the General Steel Castings Corporation. All four-wheel trucks on the railroad-owned cars have built-up alloy cast-steel trucks made by the Locomotive Finished Material Company.

The six-wheel trucks are a new type employing a triple spring or triple bolster arrangement similar to that used on all four-wheel trucks on Union Pacific streamliners in the past. These trucks have an 11-ft. 10-in. wheel base, using 36-in. diam. wheels, 6-in. by 11-in. journals and axles, with a special oversize 6 1/2-in. by 12-in. wheel seat and wheel center. The triple bolster or triple spring arrangement is somewhat different from that used on the four-wheel trucks. The main bolsters and spider are cast integral and rest on four main elliptic springs. The hangers which carry the four elliptic springs are suspended from a pair of intermediate bolsters immediately above the main elliptic springs. These intermediate bolsters are in turn supported by the intermediate helical-type bolster springs, which in turn are suspended from the truck frame through a second set of swing hangers. The equalizer springs are of the conventional type and application.

Spherical-type center plates, cast integral with the bolsters, are used on both the articulated and non-articulated trucks. Roller bearings are used throughout, the center axle being equipped with Timken bearings, and the two outer axles with SKF bearings. American Steel Foundries' clasp brakes are used with four 12-in. by 10-in. brake cylinders per truck. Two cylinders working in tandem are used on each side of the truck.

AHSC high-speed brake equipment, used on these trains, provides a braking power of 250 % of the ready-to-run weight, based on 100-lb. cylinder pressure, the arrangement being such that the cars may also be operated with the

air brake system arranged for conventional automatic braking of the usual steam trains; under this condition the braking power is automatically reduced to 60 % of that used for high-speed service, making a total of 150 % based on 60-lb. cylinder pressure during emergency and 90 % based on 36-lb. cylinder pressure for a full service application. Rapid and synchronous response on each car is accomplished by electro-pneumatic control. One No. 10 application wire and one No. 10 release wire are run through the train for this purpose. Quick stops from high speeds are made possible by use of a Decelakron, an inertia device which maintains a uniform deceleration rate, and minimizes the possibility of wheels sliding at a stop, through a tapering off of the braking torque just prior to stop. Dead-man and broken trainline safety features are incorporated in the system.

An electro-pneumatic air signal system is provided. Push buttons, labeled « Air Signal », are installed on all side doors and the rear door of the observation car. An electric impulse on this trainline operates an electropneumatic valve in the auxiliary power car to relay an air signal to the engine operator. A brake valve is provided at the rear of the observation car in addition to a push button for the electro-pneumatic horn and a switch for a back-up light. Conductor's valves are installed on each car.

Air conditioning and heating.

Air is supplied to and circulated in each car by a 1-H.P. blower furnishing 1 800 or 2 500 cu. ft. per min. through overhead air ducts to Burgess multi-vent air delivery panels in the ceiling. Exhaust fans are provided in toilets, kitchens and club rooms, and each sleeping room is equipped with its own circulating fan.

Steam floor-heat coils and steam overhead-heat coils are provided in all cars.

steam being supplied from a Vapor automatically controlled, flash-type steam generator in each locomotive power unit. The capacity of each generator is 2250 lb. of steam per hr. at 225 lb. pressure. Electric overhead heat units are provided in all cars, and in addition, electric floor heat is provided in the observation car. The connected electric overhead heat load is 28 kw. per car, plus 21 kw. additional for floor heat in the observation car.

Overhead heat is regulated by thermostats set at 68° F., 71° F., and 74° F. Floor heat in passageways, sleeping compartments and general passenger rooms is subject to thermostat settings of 65° F., 71° F., and 74° F. Individual rooms are controlled by individual thermostats of 65° F., 71° F., 74° F. and 80° F., settings.

The electric overhead heat in each car is divided into four steps of 7 kw. each. The first and second steps are cut in whenever the heating switch is closed under the control of air duct thermostats, set at 68°, 71° and 74°. The third and fourth steps are cut in by thermostats located in the air distribution ducts, which are set at 66°, 69°, and 72°. The electric floor heat in the observation car is divided into two portions, of which approximately 14 kw. is controlled by the body thermostat, set at 65°, 71°, and 74°, and an additional 21 kw. is subject to the 32° intake air thermostat.

In order to permit electric heat to be applied to the train by one engine, and the generator, either under emergency operation, or when all of the electric heat is not required, a switch is provided in the auxiliary power car to cut out No. 3 and No. 4 steps of electric heat throughout the train. The total connected electric heat load is 414 kw., which, by cutting out the third and fourth steps, may be reduced to 210 kw. The cooling system consists of dual condensing units on each car. The re-

quirements are that the system shall maintain a 76° F. dry bulb with 63° F. wet bulb temperature, with a maximum outside temperature of 120° dry bulb, 70° wet bulb. Evaporating units are located in the plenum chamber where blower air passes over them to the air ducts.

Provision is made for sequence starting of the compressor units throughout the train, in order to prevent excessive starting loads on the generators. The sequence switch is located in the auxiliary power car, and 12 sequence control wires are run throughout the train. Provision is also made that the two compressors on each car cannot start simultaneously. This is done by different thermostat settings on each compressor — these settings being 71° and 74°, and 74° and 78°.

Train lighting facilities.

Train-lighting equipment has been carefully designed to meet the requirements of individual passengers in each type of car. Indirect lighting with 32-volt lamps mounted in troughs prov-



Venetian blinds are used effectively.
Automatic telephone on the writing desk.

ides the ceiling illumination in the chair cars. In addition, individual seat lighting fixtures are combined with the luggage racks and are made an integral part of the design of these racks. These individual fixtures carry the lamps for bright illumination and six-watt blue lamps for night use, both lamps being controlled by a switch at the fixture, as well as at the switchboard in the car.

Section-type sleeping cars have two ceiling lights between sections, also reading and night lights in each berth. Room cars are all equipped with mirror, bed and ceiling lights. Special decorative illumination effects are obtained in the lounge rooms of chair and sleeping cars.

The lighting arrangement in the dining section of the kitchen-diner is designed to obtain a decorative, as well as an efficient lighting effect. A continuous moulding, housing 110-volt Lumiline lamps, is placed above the windows in such a manner that the light is reflected down upon the draperies, pier panels and tables, and at the same time is also reflected up onto the ceiling. This side lighting is supplemented by direct lights in the ceiling. These supplementary lights, together with the decorative lights at the side finish, give direct illumination.

In the dormitory-club car of the City of San Francisco a semi-circular bar is placed at the forward end of the car with top and front in dark red Mica and metal inlaid lines of yellow brass color. The front of the bar has illuminated glass panels and the back bar has a semi-circular pyramid stepped arrangement for the display of glass and liquors, with illuminated panels at the back. Amber-colored mirrors are used at the back bar, so placed as to give a circular reflection to the semi-circular bar. At the other end of the room, round corners of illuminated glass panels are employed, giving a completely new effect in room treatment. The ceilings

and lighting treatment in this car are unusual, with the lighting so designed as to become an architectural part of the ceiling treatment. The lighting is of the semi-indirect type, using 110-volt Lumiline lamps, following the contour of the room, which is further supplemented by a semi-indirect center structure, using 32-volt lamps, to provide general ceiling illumination.

The lighting in the Little Nugget car of the City of Los Angeles is in keeping with the design of the period represented. Wall illumination is provided by groups of lamps mounted in fixtures modeled from those prevalent in the gas light era. The center ceiling illumination is of the semi-indirect type, provided by 32-volt lamps mounted in troughs. The side ceiling illumination is also semi-indirect, provided by 110-volt Lumiline lamps mounted in troughs.

The ceilings of the observation-lounge car are painted in light cream and have the built-in architectural type of semi-indirect lighting, employing 110-volt Lumiline lamps. A center structure of the semi-indirect type provides secondary or general illumination.

Car step lights, together with illuminated number lights, are arranged to be lighted when the steps are lowered. Lamps are installed in ceiling fixtures of the flush type in vestibules.

Receptacles for both 32-volt and 110-volt a.c. are available in all individual rooms and wash rooms for the convenience of passengers who wish to use electric shavers or curling irons. Drawing rooms and compartments are equipped with radio receptacles having aerial, ground and 110-volt a.c. connections. Coaches, diner, observation and lounge cars are equipped with 1-tube radio sets with electro-dynamic speakers.

Rear end marker lamps are mounted in a streamlined housing on the rear curve of the observation car and are equipped with four lamps and color

enses so that trainmen can select, through a control switch, any one of three combinations on the City of Los Angeles to meet the requirements of the several railroads over which this train operates. These combinations are, respectively, forward and rear: (yellow-red), (green-green), (green-red). The City of San Francisco is at present equipped for only (green-green) and (green-red) combinations, but may be converted to a three-combination system similar to the other train. A feature of this installation is the connection of forward and rear lamps in series so that the burning of a forward light is a positive indication that a rear light is also burning.

Telephone systems.

Two independent inter-communicating telephone systems are installed in each train, one for the use of the crew and the other for the convenience of passengers. The purpose of the crew telephone system is to enable the firemen and train crew to communicate with the engineman, and it consists of six magnetic telephones, located in the engineman's cab, the second and third power cars, baggage room, dormitory-club and observation cars.

The passenger telephone system is designed to enable passengers in the sleeping and observation cars to talk with attendants in the diner and club cars. All type telephones are used, and calls may be originated in any sleeping car, the observation car, to either the dining or club cars. The last two stations may also originate calls to each other, to any other station in the system. Passengers may not, however, communicate with each other between sleeping cars, or between sleeping cars and the observation car.

A permanent telephone is mounted in each sleeping car, and in addition there is a portable telephone, complete with desk type ringer, in each of the four compartment and bedroom cars. Jacks are installed in each compartment, drawing room and bedroom, where these portable phones may be plugged in for the private use of passengers. Each portable telephone has its own call number, separate from the permanent telephone. Selective talking circuits on both the crew and passenger systems prevent other stations from listening in on a line in use. This telephone equipment was provided by the Automatic Electric Company. The usual Bell System telephone, for connection to city trunks at terminals, is provided in the observation car.

A push button and buzzer, installed in the engineman's cab, are connected to a similar push button and buzzer in the baggage compartment. This buzzer was provided in case mail-handling facilities are added later in order that the engineman may notify the mail clerk that the train is approaching a station from which a mail pouch is to be taken, and also that the mail clerk may acknowledge the signal. This line terminates in a receptacle at the rear of the auxiliary power car for the future inclusion of mail cars in the train.

Complete annunciator systems are installed in the club, dining, observation and sleeping cars. A diner signal is provided between the two articulated dining car units and a porter's signal line is installed between sleeping cars.

The same exterior color scheme is used on the new City of Los Angeles and City of San Francisco as on their predecessors, being applied in the form of synthetic enamels of Armour yellow and leaf brown with scarlet striping.

Triple-car diesel-hydraulic train for the London Midland and Scottish Railway.

Multi-engine design for miscellaneous services.

(Diesel Railway Traction, supplement to *The Railway Gazette*.)



750-B.H.P. diesel-hydraulic train for solo operation.

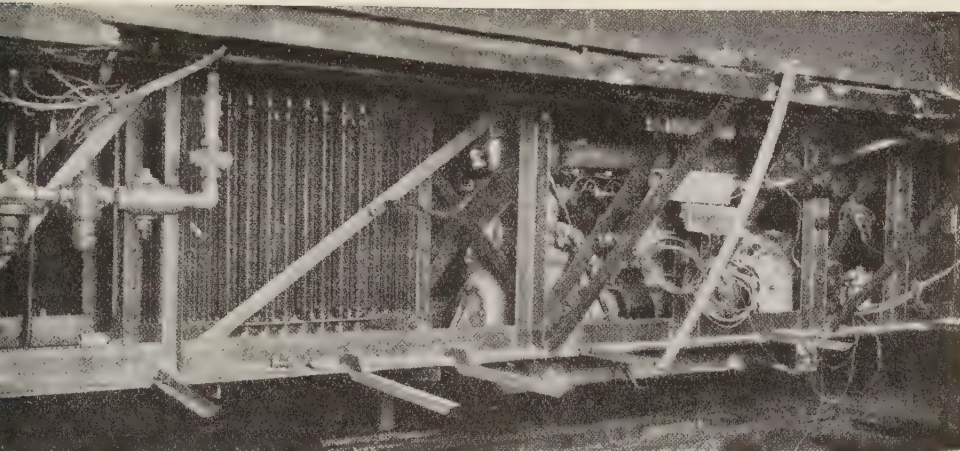
A three-car diesel-hydraulic train with multiple-unit control has been built by the L.M.S.R. at its Derby works, for passenger service first on the 77-mile cross-country line between Oxford and Cambridge, *via* Bicester, Bletchley, Bedford, and Sandy. The principal characteristic of this train is that for a power of 750 B.H.P. it has no fewer than six engines and transmission sets. The three cars are articulated into one unit, and to enable the length of each car to be up to the maximum permitted by the locking bars without the *versed sine* of the body on sharp curves exceeding the usual limits, a special form of articulation has been adopted.

Power and transmission.

A new engine model for railcar work has been developed by Leyland Motors Limited, and is used for the first time in this L. M. S. R. train. Within six 4 1/2 in. by 5 1/2 in. cylinders and a piston-

swept volume of 8.6 litres it produces an output of 125 B.H.P. at the maximum governed speed of 2 200 r.p.m., the piston speed being 2 020 ft. per min. at the brake m.e.p. 85 1/2 lb. per sq. in. The previous type of Leyland railcar engine developed 130 B.H.P. at 2 000 r.p.m. within a piston-swept volume of 10 litres, and contrasted with the direct injection of this model, the present engine incorporates a newer form of air-c combustion chamber. The crankcase is a single-piece aluminium-alloy casting and carries the fuel filter water pump and drive, etc. A six-ram C. A. V.-Bosch injection pump is fitted.

Six sets of Leyland (Lysholm-Smith) hydraulic transmission are incorporated, and are mounted along with the engines and practically all the equipment below the car floors. There are ten power-transmission sets to each vehicle and they drive separate axles, so that all the axles except the two end



Arrangement of engine and radiator within the girder underframe.

es are driven. Because of the multi-engine installation it was necessary to incorporate a free-wheel in each transmission set so that the train can overrun the engines either with the converter in operation or with direct drive.

The final drives and reverse gearboxes on the axle have a ratio of 3.12:1, and this gives a top speed of 75 m.p.h. with normal maximum engine revs. These gears are of the double reduction type in which the bevel pinion engages with two crown wheels, either of which can be engaged with a sliding spur pinion to give a change of direction of motion. This change of direction is effected by compressed air electrically controlled from the control panels.

The radiators are mounted at each end under the floor in ducts which direct a flow of air from one side of the vehicle to the other; being approximately in an S form, these ducts provide a current of air through the radiators whatever the direction of motion. Each radiator combines cooling elements for engine jacket water, converter fluid, and engine lubricating oil.

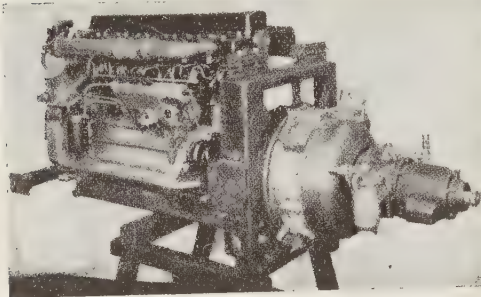
Compressed air for engine control and brakes is obtained from three engine-driven, one transmission-driven, and two

electrically-driven Westinghouse compressors. The engine-driven compressors are direct-coupled by Texropes to one engine on each underframe; the transmission-driven compressor is mounted on the propeller shaft of one engine on the centre underframe. Two dynamos, supplying current for engine and door controls and for electric lighting, are of a light type and are driven by Texropes from the propeller shafts.

Engine control.

Control of the engines and transmission sets is effected by the Westinghouse-Leyland pneumatic system. The control panel in each driving compartment is fitted with (a) self-lapping throttle control valve; (b) torque converter switch giving neutral, converter drive, and direct drive; (c) reversing switch; (d) six red lights to indicate failure of oil pressure in any of the six engines; (e) six engine starter buttons; (f) three glow-plug switches and indicator lights; (g) electrical compressor switch and indicator lights; (h) speedometer; (i) duplex air pressure gauge for brakes; (j) air pressure gauge for throttle control pipe; (k) light to indicate when sliding doors are closed.

The self-lapping throttle control valve (*a*) controls the pressure in a through train pipe. Each fuel injection pump is controlled by a small air cylinder on each engine, acting in response to variations in pressure produced in the train pipe by the movement of the valve on the panel. In the event of oil failure or low water level on any engine a valve



125-B.H.P. six-cylinder Leyland engine and Lysholm-Smith type of hydraulic torque converter.

comes into operation and cuts off the air supply to the air cylinder controlling the particular fuel injection pump without affecting the remainder. This stops the engine concerned. Owing to the free wheel in the drive, any engine which cuts out is automatically free from the train. In order to keep the engines at idling speed it is necessary to maintain a pressure of approximately 30 lb. per sq. in. in the throttle control pipe. To avoid accidentally shutting off the engines the throttle control valve is provided with a stop so that the handle can only be moved to the engine-off position by lifting a catch.

A deadman pedal is provided in each driving cab and is so connected that if pressure is released from the pedal the brakes are automatically applied, and the air in the throttle control pipe is exhausted down to a pressure of 30 lb. per sq. in., thus reducing the engines to idling speed. An interlocking circuit oper-

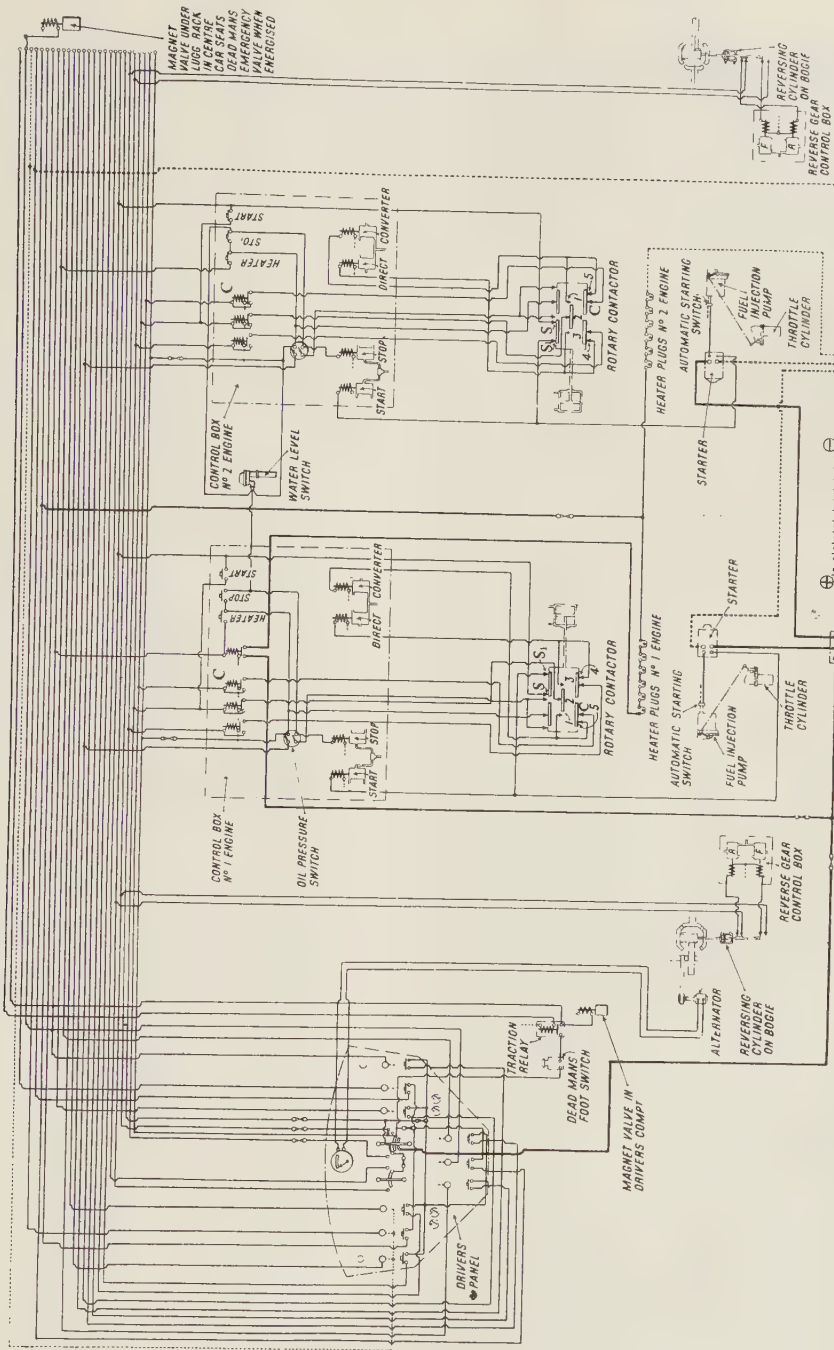
ated by the passenger sliding doors similarly prevents the throttle control pressure from being increased above 30 lb. while any passenger door is open.

Engine starting from the driving control panel is effected electrically. When each individual starter button is pressed the starter on the corresponding engine engages, and when normal idling speed is reached it is automatically thrown out of engagement and will not re-engage whilst the engine is running. During starter operation, maximum oil injection is automatically maintained on that particular engine for starting purposes.

The three positions of the torque converter clutches are given by a double-acting compressed air cylinder, under the control of two electro-pneumatic valves and a rotary contactor which cuts off the supply of air and current when the desired position is obtained. Similarly, the direction of motion of each driving axle is obtained by another double-acting air cylinder, electro-pneumatic valve, and contactor. Owing to an electric interlock with the torque converter drive a change of direction of motion can only be made when the torque converter is in the neutral position. When changing the direction of motion a lamp lights in the driving compartment and remains alight until all gears are engaged in the same direction. Each engine can be controlled from its own individual local panel, the object of which is to enable engines to be started and warmed up or examined individually.

Transmission control.

The control switches (*b*) and (*c*) for the torque converter and reversing control are used to energise the solenoid valves through suitable relays, which control the admission of air to the double-acting air cylinders on the torque converter and final drive gearbox. The switch comprises a gunmetal frame carrying a bakelite fabric base with spru-



Wiring diagram of electro-pneumatic control system, L. M. S. R. diesel-hydraulic train.

to hold the clutch in either the direct drive or converter drive settings; in these positions the clutch facings are held in engagement by the toggle action of the clutch springs which follow up wear automatically.

A drum switch, described as the rotary contactor, is provided to cut off current from the magnet valves and so place both sides of the piston in communication with the atmosphere when one of the three positions is attained. A double-acting air cylinder is mounted directly on the final drive gearbox and provided with adaptors for flexible pipe connection to the frame. A manual shifting device is provided, in the event of failure of the air pressure.

Two special switches are fitted to the reversing cylinders to ensure that these are kept charged with air while the transmission is in the neutral or converter setting, and until the piston is about $\frac{1}{8}$ in. to $\frac{1}{16}$ in. from the end of its travel, when the air is cut off from the cylinder.

Two types of magnet valves are used, one for the clutch and reversing cylinders and for the admission of full reservoir pressure to the throttle cylinder in starting, and the other for reducing the throttle cylinder to atmospheric pressure or stopping the engine. In the first type the supply port is coupled to the cylinder port when the coil is energised. In the second type the cylinder port is coupled to the atmospheric port when the coil is energised.

Each double-acting cylinder is controlled by two magnet valves, which can only be energised alternatively. The consumption per valve is 0.15 amp. at 24 volts. There are three train wires associated with the converter control, each fed in one of the three positions of the switch and each feeding in turn a separate solenoid relay. When any one of these three relays is energised, contacts are closed in opposition to springs, completing the circuit from the battery posi-

tive up to the appropriate contact on the rotary contactor, which unit performs the final stage in the converter control. These relays are wound to withstand continuous service with low current consumption.

The rotary contactor is mounted in the torque converter clutch housing, and comprises a small cam-operated switch with the cam mechanically linked to the clutch control arm. The switch consists of a central cam spindle which operates on spring-loaded arms carrying platinum points, and contacting with fixed platinum points in such a manner as to make and break circuits originally closed or preselected at the panel in accordance with the movement of the clutch lever. The switch is housed in an aluminium casing.

Contacts 1, 2, and 3, which are housed in the cover supporting the rotary contactor, are provided with adjustment which permits the platinum contact points to make or break circuit earlier or later as required. These contacts are used for finding the neutral position on the torque converter clutch operating lever, and permit a very fine adjustment to be made, thus preventing unnecessary hunting on the clutch operating lever. A pointer is fixed to the end of the cam spindle, and the base for the contacts (housed in the cover supporting the rotary contactor) has a raised portion with a line scribed on it. When the end of the pointer coincides with the scribed line, the electrical centre of the rotary contactor is found.

These circuits are those controlling the two magnet valves for the clutch cylinder, the starting motor, and the oil pressure switch; the contacts are so arranged that they give three positive positions of the clutch mechanism in accordance with the panel switch positions, and also break the feed to the magnet valves when the clutch is actually in either direct, converter, or neutral setting, thereby relieving the clutch

ball race of load and preventing waste of air or electricity. When the neutral setting is selected on the converter control switch, the neutral relay is energised, thus connecting the battery positive with the contact 2.

To understand how positively the control is held in the neutral position under these conditions, it is only necessary to consider that the bar is moved to the left by some outside influence; this would bring the middle segment into contact with point 1, energising the converter drive valve and admitting air to the left hand side of the piston, with the effect of restoring the bar to its original position. A similar action would take place in conjunction with terminal 3, if an external force should tend to cause movement to the right from the central setting.

Considering the bar in the neutral position, if the converter solenoid relay were energised, the battery positive



Driving position of L. M. S. R. train.

would feed through *C* and 5 to the converter valve, causing the piston to move to the right-hand or converter end; some time before completion of the travel the point 5 would lose contact with its segment, de-energising the magnet valve and leaving the piston with atmospheric conditions on both sides; under these circumstances the toggle action of the clutch springs is sufficiently powerful to complete the motion.

The fourth contact piece is provided with contacts for completing the circuit for the starting motor when the rotary contactor is in the neutral position only. No circuit is obtainable when the contactor is in the converter or direct drive setting. The fifth contact piece is provided with contacts which interrupt the circuit to the oil pressure switch when the transmission is in the neutral setting.

The oil pressure switch operates to close contacts with a falling oil pressure at 6 lb. per sq. in. and to open contacts with a rising oil pressure at 8 lb. per sq. in. A falling pressure would result from engine stoppage, or from any defect in the lubrication system such as broken or leaky pipes, faulty pump, or lack of oil, or a fractured engine oil sump. It also occurs simply as the result of normal engine stoppage.

There are two independent circuits, one used to feed an oil pressure light on each panel, thus indicating the defective engine, the other used to energise the stop magnet valve, to stop the engine as the result of any oiling defect, providing such defect occurs when the transmission is in the direct or converter drive settings. The contacts are operated by expansion of a metallic bellows which is designed to withstand a pressure of 16 lb. per sq. in. A quick break is ensured by a permanent magnet. The contacting pressure is indicated on a visible scale and can be adjusted by a large external knob which can be locked or sealed.

The oil pressure switch, double check valve, and all relays and magnet valve required for the control of the throttle

and torque converter for each engine are mounted in a dust-proof casing mounted on the underframe. This box has a sheet metal cover retained by spring fasteners. Two 12-pin couplings having self-aligning contacts are provided to permit removal of the box without detaching any of the wires leading to or from the box. The connections are made clear by figures stamped on the coupling body. The two magnet valves for the control of the reversing gear for each final drive are mounted in another dust-proof casing mounted on the underframe and near to the final drive gearbox, and this box also has a sheet metal cover retained by spring fasteners.

Tell-tale apparatus.

The low-water switch has two mercury switch tubes which operate to close contacts when the water in the engine cooling system falls below a certain level as the result of prolonged boiling, or leaks in the radiator or piping. It operates in conjunction with two adjacent engines, and has two independent circuits, each used to energise the stop magnet valves to stop the nearest engine.

The actual contacts are formed by short wires sealed *in vacuo* in a glass tube containing a small quantity of mercury. The tubes are held in a metal casing mounted on a pivot and so arranged that when a float falls below a certain point the tubes are overbalanced and suddenly tilt over to an angle of 30°, causing the mercury to bridge the wires and energise the throttle isolating switch, stopping the engine. When the water is at the correct level the mercury tubes are held firmly at an angle of 30° to the open circuit condition by the buoyancy of the float, this angle being sufficient to prevent car movement from affecting the action. The switch and actuating mechanism are fully enclosed in a dust-contained assembly which is applied to one water reserve tank on each car

mounted above the level of the cylinder head and coupled to the radiator.

Control of the throttle is effected by providing for each fuel injection pump a small air cylinder arranged to thrust against calibrated springs for the regulation of the fuel delivery in accordance with pressure in the train pipe regulated by a self-lapping valve in the driving compartment. The springs which tend to return the fuel control lever to a position of zero delivery have a differential rate, arranged so that a given pressure causes the control to move to the idling position, but further movement beyond this point involves a considerable increase in pressure.

The double check valve consists of a cylinder with a free piston. The cylinder is connected by pipes at either end to the stop and start magnet valves, and in the middle to the throttle response cylinder. When air is admitted through the start magnet valve, the piston is blown over, sealing the opening to the stop magnet valve, and uncovering the opening to the throttle response cylinder. The reverse action takes place when air is admitted through the stop magnet valve. Due to the low pressure required to give idling position on the throttle response cylinder, the piston is spring-loaded for movement in this direction.

Engine starting and stopping.

A special form of automatic starting switch has been evolved by C. A. V.-Bosch for application to this train; it is attached to the fuel pump and operated by the combined action which the throttle lever and the pump governor exert on the rack. The conditions for starting an engine from the control panel are :

(1) The engine must be practically stationary; (2) there must be sufficient air pressure in the main reservoir to enable the throttle response cylinder to operate to the full throttle position; (3)

the transmission must be in the neutral setting.

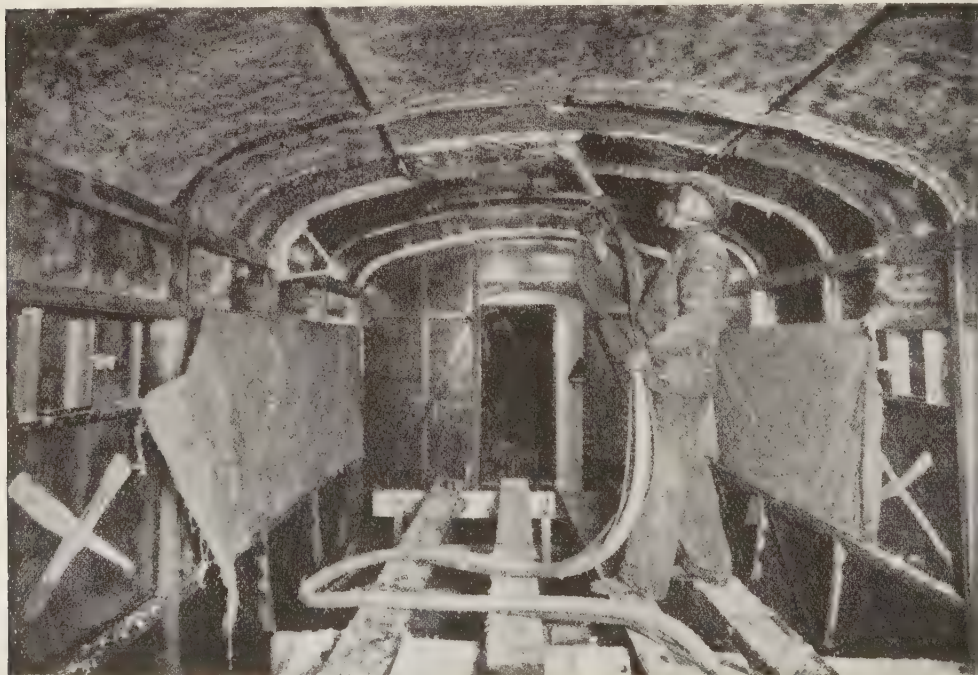
The positive feed to each switch is taken from a neutral contact on the converter control switch, and is only live when the switch is in the neutral position.

The feeds from the switches are taken through contacts *S* and *S1* on the rotary contactors, to the start magnet valves. The magnet valves admit air from the main reservoir through the double check valves to the throttle response cylinders, which operate to move the fuel pump levers to the full throttle position, and close the fuel pump starting switches. Simultaneously, a feed from the start magnet valve energises the starting motor solenoid, engaging the starting motor, the circuit being completed through the fuel pump starting switch to the battery negative. The driver's throttle control

valve must be set to give not less than idling speed of the engine, so that the engine will continue to run at a definite speed after starter engagement.

Since there is no oil pressure in respect of a stopped engine, the normal action of the oil pressure switch is prevented when starting by taking the feed to the oil pressure switch which energises the stop magnet valve through contacts on the rotary contactor which are broken when neutral is engaged, but closed in direct and converter drive. This means that defective oiling will not prevent the starting of an engine and it will continue to run while the transmission remains in neutral, but as soon as the converter is engaged prior to moving the train, the oil pressure switch will cause the stop magnet valve to operate to stop the engine.

The starter button is not to be held



Spraying the interior of the L. M. S. R. diesel train with Roberts's asbestos insulation

own for a prolonged period after the starter has disengaged, otherwise the engine will be racing unnecessarily on the governor of the fuel pump. With the driver's throttle control valve set to give idling speed on the engine, the engines come to the idling speed when the starter button is released.

To obviate the necessity of having long or repeated starter engagements, due to difficulty in starting the engines on a cold morning, heater plugs are fitted to each engine. The heater plugs for two adjacent engines are connected in series, the battery positive to the heaters being carried through a relay in one of the adjacent control boxes. This relay is fed from a push-button switch on the control panel. In the event of the engines being started locally from the control box, a heater push-button switch is provided in the control box, closing the heater relay, which when pressed closes the relay and completes the heater circuit.

For examination and inspection purposes, it is sometimes necessary to be able to start an engine locally. To enable this to be done a push-button switch is installed in the control box. If there is full pressure in the main reservoir, it is only necessary to press this switch, and, providing the transmission is in the neutral setting, the engine starts. For the case where the pressure is low in the main reservoir, a mechanical linkage is provided on engines Nos. 2, 4, and 5, to enable the fuel pump lever to be moved into the idling throttle position, thus closing the contacts in the fuel pump starting switch. After starting under these conditions, engines Nos. 2, 4, and 5 should be run until full pressure is registered in the main reservoir, when the other engines may be started as described above. In preparing the train for service in the morning each engine is started from cold by using these local controls; in this way the driver can listen to the running of each engine and observe the

action of the various component parts in the control box.

A push-button switch is provided in each control box for stopping individual engines. This switch energises the stop magnet valve and brings the engine to rest. Where it is desired to isolate the engine out of action, stop cocks are provided on the control box to enable the pneumatic apparatus to be isolated from the main reservoir.

On each driving panel are fitted six indicator lights for low oil pressure, and three indicator lights for the heaters. The oil indicator lights glow as the result of the closing of the oil pressure switches. In starting up the engine, the converter control switch handle is first put into its socket in the panel, automatically energising the neutral and positive feeds and causing the oil indicator lights to glow at both panels. Upon starting the engines the indicator lights go out. If any light continues to glow after a reasonable number of starter engagements of that engine, the faulty unit is locked out of action by closing the isolating cocks on the corresponding engine control box, and the trouble investigated. The oil pressure lights also glow as the result of an engine stopping due to lack of water in the coiling system.

Car lighting and engine starting current.

Electricity for lighting, engine starting, engine control, and air compressors, is provided by two Stone's Tonum 125-amp. generators, each driven from one of the power transmission shafts by three endless vee belts of the Texrope type. Control of the output is by Stone's dynamo field regulators with which are combined cut-in and light switches. The 12-cell batteries are of Chloride manufacture and are composed of special Exide Ironclad cells, in wrapped ebonite boxes, of 390 amp.-hr. capacity at the 10-hour rate.

One of these equipments is installed on each of the outer cars of the train and

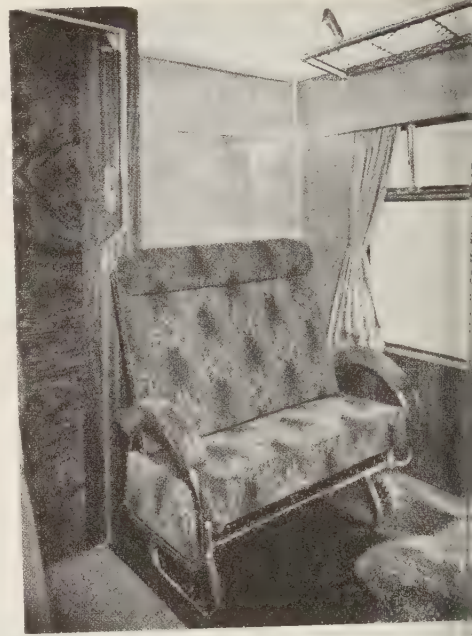
supplies the lighting on the outer coach and on one half of the centre coach. Lighting throughout the train is under the control of the guard from either guard's compartment, and is in two circuits, with the lights in groups of two bulbs down each side of the ceilings. Current for engine starting on the centre car is provided by a bus-type generator driven from one of the propeller shafts on this car, the battery being of the same type and voltage as on the outer cars, but of 210 amp.-hr. capacity.

Car bodies and underframes.

The body framing is of the timber type with outer panel plates of steel sheets welded together by the carbon arc process before being screwed to the timber framing. The carlines are of timber-filled steel construction bolted to the cantrails, and the steel roof sheets are secured to these by arc welding. The teak pillars of the body are bolted into steel pillar brackets welded to the solebars. The floor is made up of 18 s.w.g. dovetail steel sheeting welded to the level top of the underframe, and is overlaid with J. W. Roberts's Nonpareil cork, and with felt, and linoleum.

Air operated Alpac sliding doors give access to the interior, and these are under the control of the guard. They are interlocked with the engine control so that the driver cannot start the train while any sliding door is open. Passenger control push switches are fitted to the doors so that they can be opened by the passengers, provided the guard has previously set the control for this purpose. The door motors are mounted below the seats adjacent to the entrance bulkhead, and these particular seats are arranged longitudinally instead of transversely.

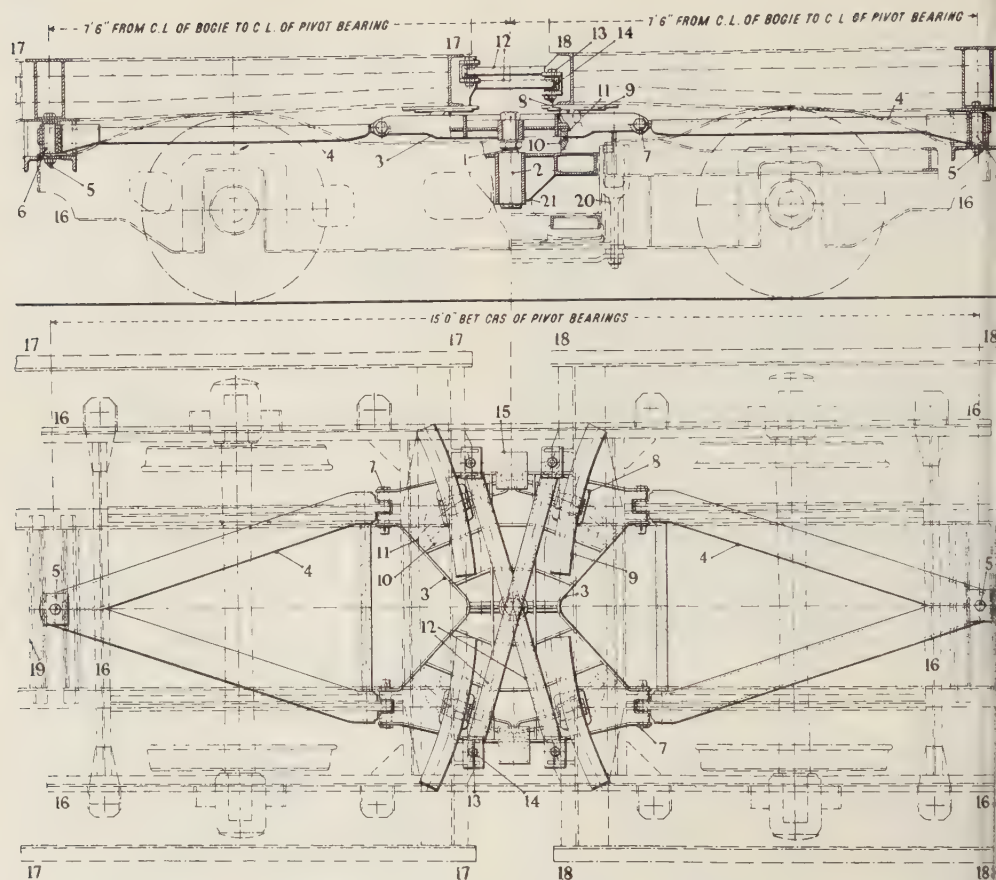
The interior of the cars is panelled in veneered three-ply, and all partitions have been made hollow for the sake of lightness. The veneers in the third class



Interior of first-class compartment.

are figured white birch above the waist level and West African cherry mahogany below, with mahogany framing members. In the first class the panels are veneered in Pacific quilted maple above waist level and Circassian walnut below. In this class a pleasing effect is obtained by the use of decorative mouldings of satin finished aluminium alloy.

All the transverse seats except those against cross-partitions are of the tubular type. They are mounted on chromium-plated steel tubular frames made by G. D. Peters & Co. Ltd., and have Dunlopillo fillings; the trimmings are of uncut moquette in shades of blue and brown for the first class and in blue and brown for the third class. The seating layout and capacity are shown on one of the diagrams accompanying this article. A large number of the interior fittings, such as luggage racks, brackets, door handles, torpedo ventilators,



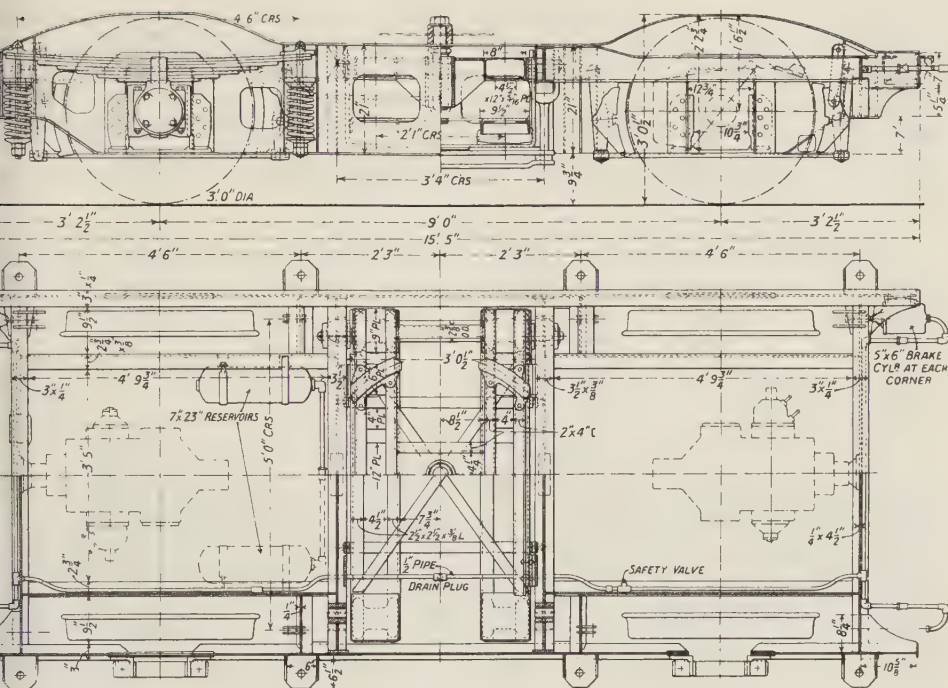
General arrangement of articulation system.

- | | | |
|---|---|--|
| 1 — Centre pin. | 8 — Roller support to underframe. | 15 — Lubrication to roller bearings. |
| 2 — Silentbloc bearing to centre pin. | 9 — Race plate to roller support. | 16 — Articulated bogie. |
| 3 — Articulating link (centre section). | 10 — Bogie bolster friction block. | 17 — Framing members to first car. |
| 4 — Articulating link (end section). | 11 — Friction plates to friction block. | 18 — Framing members to second car. |
| 5 — Pivot pins to links. | 12 — Centring rods. | 19 — Supporting frame to pivot bearings. |
| 6 — Silentbloc bearing to link pins. | 13 — Pins to centring rods. | 20 — Swing beam to bogie. |
| 7 — Pins to knuckle joints. | 14 — Silentbloc bearings to centring rod. | 21 — Bogie centre framing. |

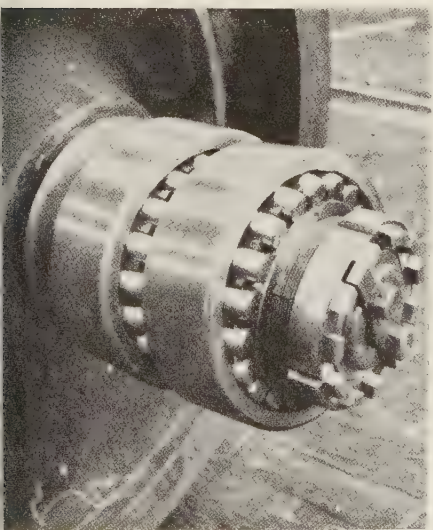
heater casings, curtain rails, decorative mouldings, and window fittings are of aluminium alloys supplied by the Northern Aluminium Co. Ltd. and these fittings were treated by the Aluminite process. Bakelite ashtrays are fitted to the side panels below the windows.

Sliding ventilator lights made by Worcester Windshields Limited are mounted above the fixed windows, and they

are supplemented by torpedo extractors in the roof. Most of these communicate with the interior of the body, but several are used for ventilating the air space between the outer roof panels and interior ceiling finish. In this way condensation on the insides of the steel panels is reduced to a minimum. Three lavatories are provided, and have green painted walls and aluminium alloy mouldings.



General layout of non-articulated bogie, L. M. S. R. diesel train.



S. K. F. axle roller bearing.

ings. Hot and cold water is available, and the hot water is provided by means of a water heater of the Westinghouse type.

The under surface of the flooring near the engines is insulated with Roberts's Limpet sprayed asbestos 5/8 in. thick, and elsewhere 1/4 in. thick. The inside surfaces of all the valances, body sides, and roof panels are sprayed with Limpet asbestos to a thickness of 1/4 in., and in this manner a large measure of both heat and sound insulation is obtained. A newly developed form of Clarkson boiler has been incorporated for the heating of the train, and goes within a very confined space.

The underframe of each car is completely welded, and is fabricated of Kuplus copper-bearing steel having an ultimate tensile strength of 37-43 tons per sq. in. and a yield point of 22-23

tons per sq. in. The main longitudinals are the inner pair, and these are of lattice girder construction with a depth of 2 ft. 9 in., and 5 in. by 3 in. by 7/16 in. angles top and bottom. These centre girders carry the engines and radiators as well as their share of the car body load. The outer solebars are of 5 in. by 3 in. angles. Particularly stiff diagonal bracing has been incorporated at the extremities of the end cars, two girders being used, one of which is cut away where it crosses the other.

All four bogies have welded frame structures of Kuppl steel, and all have Taylor Bros. disc wheels 3 ft. in diameter spread over a wheelbase of 9 ft. The axles are hollow-bored to the extent of 2 to 2 1/2 in. and are carried on S.K.F. roller bearings supported by independent overhung laminated springs. Helical steel auxiliary springs are fitted round the hangers and they are encased in light steel covers. Helical springs also support the welded steel bolster. The Westinghouse brake is of the self-lapping automatic type and applies two blocks on each wheel through clasp rig-

ging. The brake blocks have Ferod linings. Individual cylinders, 5 in. in diameter, are used for each wheel, and the amount of brake rigging thereby is considerably reduced. There is a hand brake in each driving position, and it applies the blocks on the adjacent bogie only.

In the system of articulation used to connect the centre vehicle to the other two, four rollers are used to carry the weight of the two underframes and transmit it to the bolster, and the pivoting is carried out through two pins (5 in the drawing) located on the underframe above the extremities of the bogie frame structure. These two pivots are connected by a long link system consisting of the links 4 and the welded steel centre member 3, which to allow of relative vertical movement are connected by the knuckle pins 7, and the centre structure also is pivoted to the bogie through the centre pin 1, carried in a Silentbloc bushing 2. The end pivot pins 5 and the pins of the centring rods 12 also are carried in Silentbloc bushings.

MISCELLANEOUS INFORMATION.

1. — Conversion of "Atlantic" type locomotive No. 3279, London and North Eastern Railway.



Through the courtesy of Sir Nigel Gresley, B.E., Chief Mechanical Engineer, London and North Eastern Railway, we publish a description of the conversion of Engine No. 3279, which was originally built as a two-cylinder Ivatt Atlantic in 1904 and numbered 279, subsequently being converted to a four-cylinder simple engine in 1915. The cylinders were 15" diameter by 26" stroke and the outside valves which were placed above the cylinders were operated by Walschaerts gear. The inside valves were placed beneath the cylinders and were actuated through rockers from extensions to the live spindle of the outside cylinders. In order to accommodate these cylinders a new coupling link bogie was fitted having wheels 2' 2" diameter instead of 3' 8" as on the standard bogie. A 24-element superheater was also fitted.

In this form the engine ran, from 1915 to 1937, a mileage of 629 300 between London and the North, and in the later years fre-

quently worked the « Queen of Scots » Pullman Express.

During its latest overhaul the engine has been converted to a two-cylinder engine. The cylinders are the same pattern as on the K. 2 type engine. They are 20" diameter by 26" stroke and are fitted with 10" diameter piston valves operated by Walschaerts gear.

The valves have a lap of $1 \frac{9}{16}$ ", a lead of $\frac{3}{16}$ " and line and line exhaust. The valve travel at 70 % cut off is 6".

The exhaust ports are carried through a cast steel smokebox saddle to the blast pipe base. In line with modern practice, a more commodious cab has been provided and the frame at the trailing end has been lengthened accordingly.

In its new form the engine weighs 70 tons 14 cwt., of which 40 tons is carried on the coupled wheels.

The tractive power at 85 % of the boiler pressure is 18 785 lb. and the factor of adhesion is 4.77.

170 LB/300 W.

WATER 3500 GALLONS

COAL 6 TONS

Dimensions: 5' 4", 6' 0", 7' 0", 13' 0", 4' 2", 3' 5", 8' 0", 26' 4", 6' 10", 5' 3", 6' 2", 4' 0", 8' 6" OVER SUMP, 8' 0" OVER FOOTPLATE.

Empty weight: 15-8, 12-18, 43-2, 14-6, 20-0, 18-6, 70-14.

Maximum weights in working order: 15-8, 12-18, 43-2, 14-6, 20-0, 18-6, 70-14.

BE-BUILT 1938

<i>Height</i> :	5' 2"
Length on slope	5' 11 5/8"
Width	3' sq. ft.
Grate area	
<i>Factor</i> :	
Height of crown above foundation ring	5' 11 3/16"
Interior length at top	5' 3 11/16"
Interior width at boiler centre	5' 7 7/16"
Thickness of sides and back	4' 9"
Copper plates	9/16"
Insulation	1" and 9 1/2"
<i>Boiler</i> :	
Outside length of firebox, overall	6' 6"
Inside length of firebox at bottom	5' 11"
Outside width of firebox at bottom	5' 6"
Diameter of barrel	15' 6 3/8"
Length of barrel	5' 8"
Thickness of barrel plates	5/8"
Thickness of wrapper plates	6' 0"
Diameter of smokebox	5' 9"
Inside	

<i>Tubes, superheater flues :</i>		
Number	24	
Diameter outside	2 1/4"	
Thickness	5/32"	
Length between tubeplates	15 1/2 3/4"	
<i>Heating surface :</i>		
Firebox	141 sq. ft.	
Tubes	1 355.5 —	
Flues	526.5 —	
Total evaporative	2 023 —	
<i>Superheater :</i>		
Number of elements	24	
Diameter inside	1 1/4"	
Heating surface	427 sq. ft.	
Total heating surface	2 450 —	
Two Ross non-safety valves	3" diam.	
Working pressure	170 lb. p. sq. in.	
<i>Artes :</i>		
Journals, pony	Dia. 5 3/4" × 9"	
— coupled	8 1/2" × 9"	
— trailing	5 1/2" × 10"	
<i>Crank pins :</i>		

	ings.—Bore:	Hetical,	10	1/4"	long tire, coupled outs diam., Tinnus section, wheels : Laminated, 11 plates, 5" 3' 6" crs.: Driving : Helical, 11 6 1/4" outs. diam., Tinnus sec- Laminated, 10 plates, 4 1/2" 4' 6" crs.	wide 58" thick. ing tree, the ring, Tinning: 58" thick.
Cylinders :						
Number 2 "	
Diameter "	" 20 "	
Stroke "	" 26 "	
Motion :						
Type of valves	Walschaerts.
Diam of valves	Piston.
Max. travel of valves	10".
Suction lap	6".
Exhaust lap	1 9/16".
Cut-off in full gear	Nil.
	70 %
Traction effort at 85 % boiler pressure	18 785 lb.
Total adhesive weight	89 600 lb.

Adhesive weight.

[631. 538 (73)]

2. — Light weight double-deck electric train in experimental service on the Long Island Railroad.

(*Modern Transport.*)

In furtherance of studies aimed to increase the carrying capacity of passenger cars, the Long Island Railroad, on December 28 last, placed in operation two newly constructed lightweight experimental all-aluminium double-deck electric passenger coaches. The new double-deck cars will be operated for several weeks as part of eight different scheduled trains running every week-day from New York over three branches of the railway — namely, those to Port Washington, Hempstead and Montauk.

It will be recalled that in 1932 the Pennsylvania Railroad ordered for its Long Island subsidiary a double-deck coach 14 ft. high, in which the seats were interlaced and all were approached from the same main floor. No sill was needed with this form of seating, and the tare per seated passenger was reduced to 597 lb., the total weight being 32 long tons and the number of seats 120. This car had an overall length of 74 ft. 4 3/4 in., and the seats per foot run of length were 1.6.

This may be compared, among other modern double-deck railway coaches, with the South African Railways' 3 ft. 6 in. gauge well car of 1926, which seated 128 passengers, 2.0 per ft. run, at a tare of 532 lb. a seat; the French State Railways car of 1933, seating 115, or 1.5 per ft. run, and scaling 900 lb. a seat; and the Lübeck-Büchen twin articulated set of 1935, seating 150, 2.0 passengers per ft. length, or 478 lb. a seat.

The previous Long Island double-deck coach was placed in service in the late summer of 1932 on various steam trains, and was the first of its kind on an American trunk railway system. Favourable reaction to its use on many parts of the Long Island Railroad has prompted additional tests with the substantially improved units just constructed. In the new cars use is made of the knowledge and experience gained in the operation of the original double-deck coach. The new cars are longer and have greater seating capacity than the one in use during the past five



Fig. 1. — Double-deck electric train, Long Island Railroad.

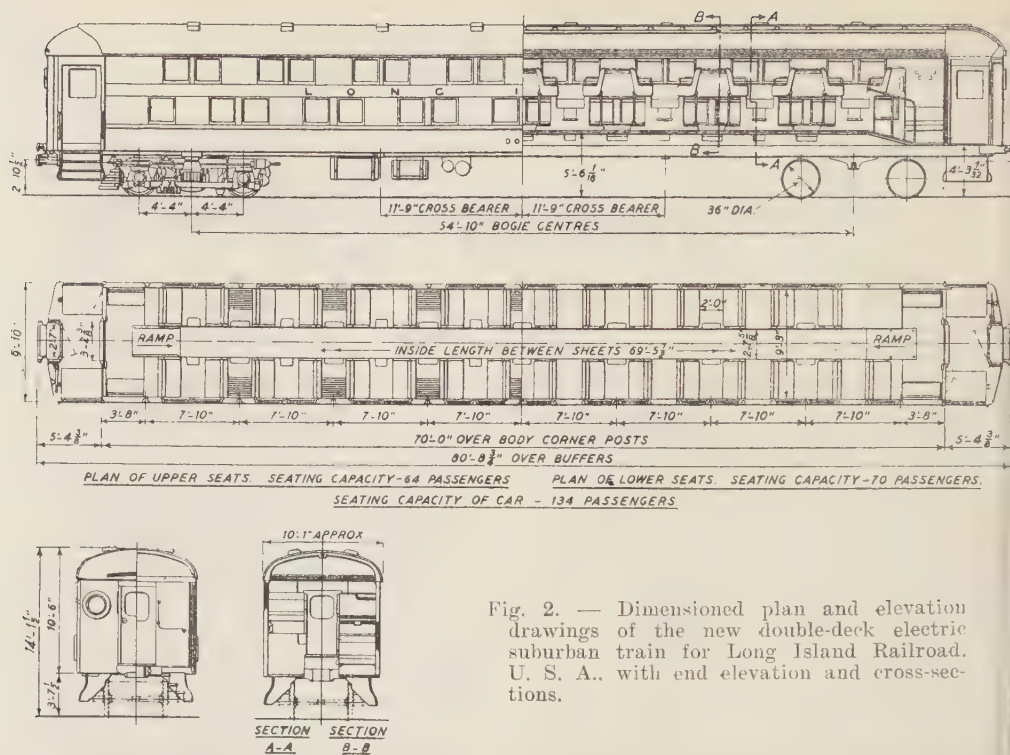


Fig. 2. — Dimensioned plan and elevation drawings of the new double-deck electric suburban train for Long Island Railroad, U. S. A., with end elevation and cross-sections.



Fig. 3. — Interior of Long Island Railroad double-deck coach.

years. The overall length of each is 80 ft. 8 3/4 in., and there are seats for 134 passengers. The width is 10 ft. 1 in. and the height 14 ft. 1 1/2 in. From the accompanying drawings the method of placing the foot well of pairs of upper seats between the backs of the lower pairs will be appreciated. It is by this interlacing that the capacity is improved compared with the separated decks of the French State units, while a cranked frame becomes unnecessary.

One of the new cars is equipped with four high-speed motors, two on each bogie, and the other is a control trailer, equipped so that the motorman may operate from either end. The weight of the new motor-equipped double-deck coach is 40 tons, while the trailer without motors weighs 35 tons 14 cwt. As compared with these weights, the standard all-steel passenger coach now in use on the Long Island measuring 64 ft. overall, weighs with its motors 70 tons 17 cwt., and accommodates 80 passengers, or 56 less than the new light-weight cars. The new cars, therefore, seat 1.65 passengers per ft. of length, which

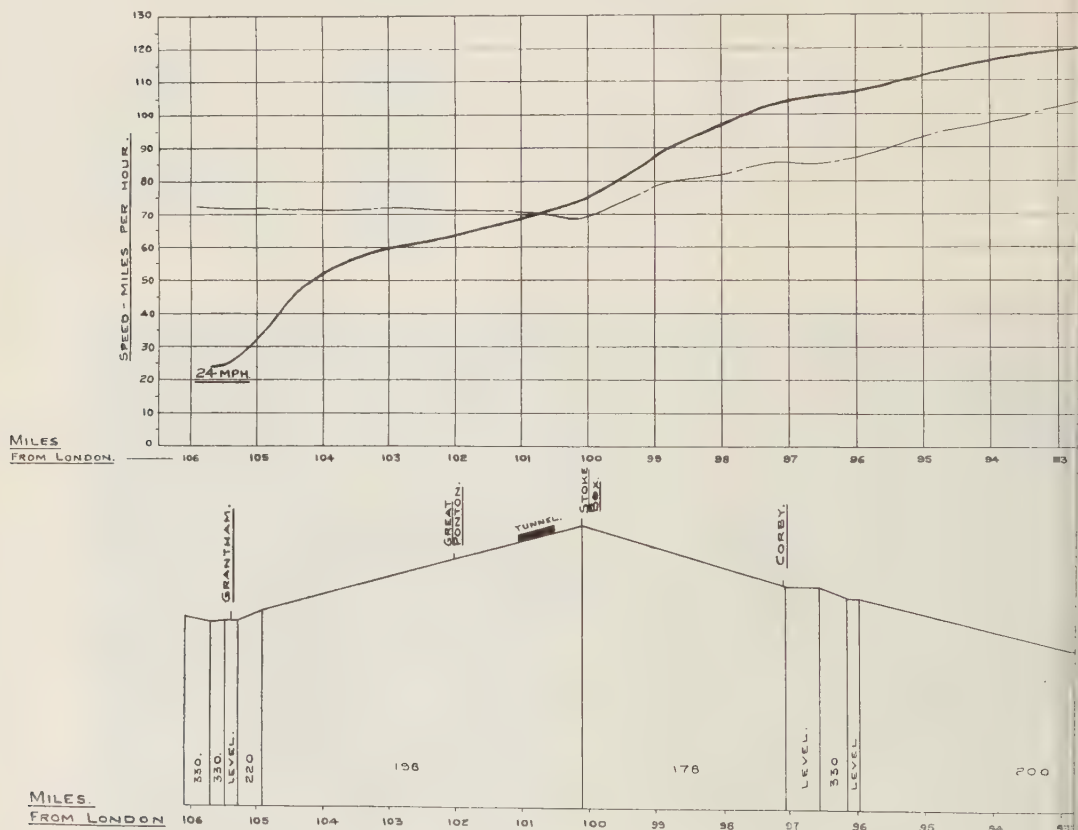
compares unfavourably with the L.N.E.R. London suburban coaches, seating 1.9 passengers per ft. run, or the Southern Railway electric trailer cars, seating 1.8 persons per ft. run. The tare per seat is 672 lb. in the case of the motor coach and 597 lb. for the control trailer. The comparative figure for L.N.E.R. suburban coaches and S.R. trailers is 550 lb., but an average Southern electric suburban set of eight cars weighs 917 lb. per passenger.

The new Long Island double-deck cars will be operated in the electric territory, where the railroad is confronted with the need for increased carrying capacity, reduced weight and maximum efficiency of operation in the extremely dense traffic handled in and out of New York over the tracks of the Long Island Railroad. The novel seating arrangement is claimed to assure the utmost comfort and convenience to passengers. Ample space is provided between the seat cushions for convenience in entering and leaving, and both upper and lower tiers have two windows to each pair and suitably placed parcel racks.

[656. 222.1 (.42)]

3. — High-speed trial run with the « Coronation »

We reproduce hereafter, by courtesy of Sir Nigel GRESLEY, C.B.E., Chief Mechanical Engineer, London and North Eastern Railway, a diagram showing the speeds attained during the trial run with the « Coronation » train on Sunday, July 3rd. Superimposed on this

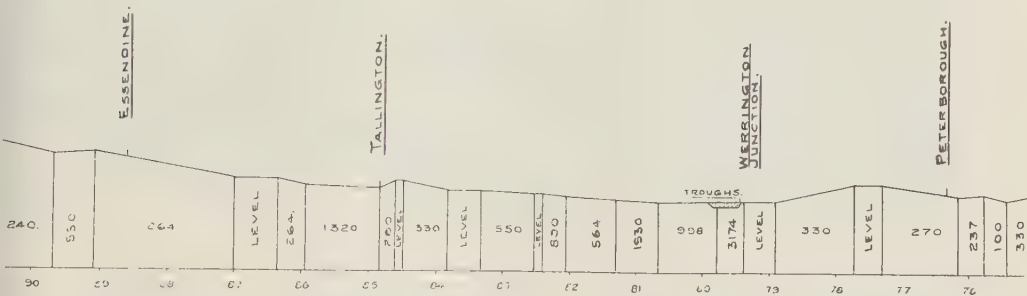
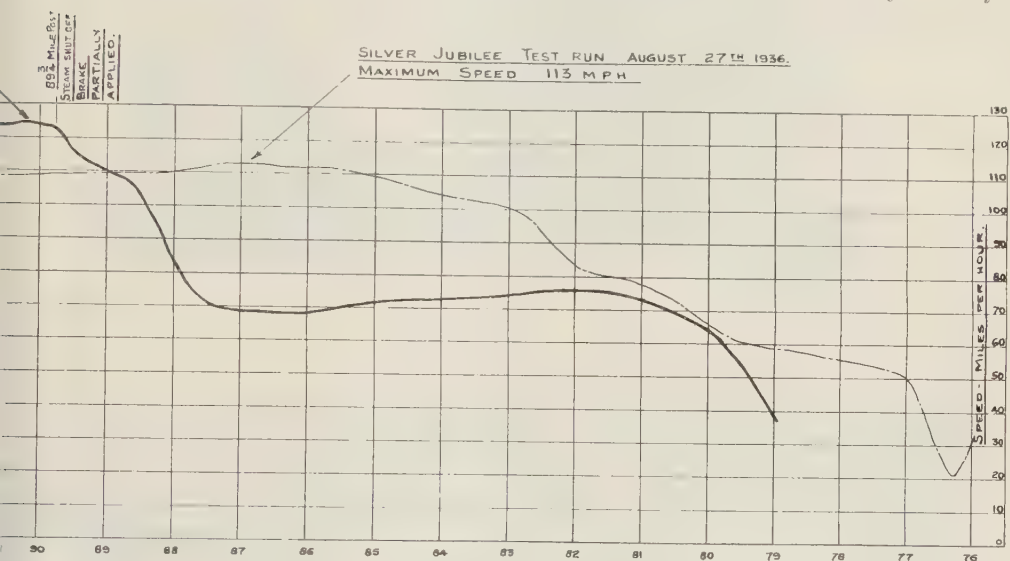


Speed curve for London and North Eastern Railway « Coronation »

rain, London and North Eastern Railway.

diagram is a record of the test run made by the « Silver Jubilee » on August 27th, 1936, during which a speed of 113 m.p.h. was attained.

We also give a list showing mileposts and passing times for the journey on July 3rd.



in with dynamometer car. — (July 3rd, 1938).

High-speed run with No. 103 Coronation set vehicles with dynamometer car —
 Weight : 236 1/2 tons. — Engine No. 4468 "Mallard". — Sunday, July 3rd, 1938.

Station.	Miles from London.	Passing times.	Speed, m.p.h.	Cut-off.	Remarks.
Grantham	105 1/2	4-24-19	24	40 %	
	105	4-25-13	32	»	
	104	4-26-32	52 1/4	»	
	103	4-27-36 1/2	59 3/4	30 %	
(St. Ponton	4-28-31	...	»	
	102	4-28-35 1/2	63 1/2	40 %	
	101	4-29-30	69	»	
	100	4-30-20 1/2	74 1/2	»	
	99	4-31-5	87 1/2	»	
	98	4-31-44 1/2	96 1/2	»	
Corby	4-32-17	103 3/4	»	
	97	4-32-20 1/4	104	»	
	96	4-32-54 1/2	107	»	
	95	4-32-27 1/2	111 1/2	»	
	94	4-33-59 1/2	116	40 % at 93	
	93	4-34-30	119	45 % at 94 1/4	
	92 3/4	...	119 1/4	40 %	
	92 1/2	...	120 3/4	»	
Little Bytham	92 1/4	4-34-52 1/2	122 1/4	»	
	92	4-35-00	122 1/2	»	
	91 3/4	...	122 1/4	»	
	91 1/2	...	123	»	
	91 1/4	...	124 1/4	»	
	91	4-35-29	124 1/4	»	
	90 3/4	...	123 1/2	»	
	90 1/2	...	124	»	
	90 1/4	...	125	»	
	90	4-35-58 1/2	124 1/4	»	
	89 3/4	...	123	Steam off — Brake on.	
	89 1/2	...	116	...	
	89 1/4	...	113	...	
	89	4-36-29	110	...	
Essendine	88.65	4-36-40	107 1/2	...	
	88 1/4	...	95	...	

[621.133.7 (.42)]

4. — Water softening plant of 40 000-gallon hourly capacity,

London and North Eastern Railway.

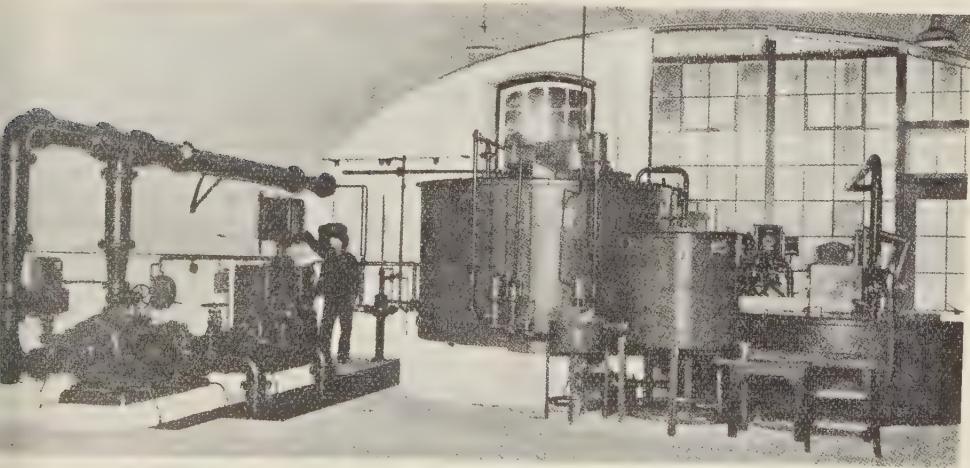
(The Railway Gazette.)

By the courtesy of Sir H. Nigel Gresley, we were recently able to inspect the water softening plant illustrated. It is a lime-soda water softener supplied by the Permutit Co. Ltd., and installed at Spitalfields in the vicinity of

Liverpool Street station. The plant is of the cylindrical type, built for a continuous hourly capacity of 40 000 gallons. The raw water is drawn from the Metropolitan Water Board's mains, and the initial hardness of 16



Plant viewed from rail level, showing the filter press housing.



Chemical proportioning and measuring gear, and pumping equipment at ground level.

18 degrees Clark can readily be reduced to degrees or less by the softening process. The settling tank is of riveted mild steel

construction with dimensions of 36 ft. diam. by 46 ft. 9 in. high, allowing a total settling time of 4 hours; the tank is erected on a re-

inforced concrete structure so that the tank base coincides with rail level, and the Permutit P.M. type ground-operated lime and soda measuring apparatus is housed in an arch below the track. This apparatus is arranged to give a proportionate dosing of lime and soda at all rates of flow, by the use of a special contacting water meter fitted in the pipeline, which carries the hard water to the inlet point on the settling tank.

The lime and soda emulsion is stored in a cylindrical mild steel tank measuring 9 ft. diam. by 5 ft. 6 in. deep, and the emulsion is kept permanently in an evenly mixed condition by means of a motor-driven agitator. At the base of the tank, there is a valve box housing the positive type discharge valve, which is actuated by a powerful solenoid attached to a bracket at the top of the tank. The solenoid is wired up with the electrical contacting meter on the crude water inlet pipe, and the arrangement of the meter is such that the contacts close after the passage of a unit number of gallons. At each contact the solenoid is energised, thereby opening the valve, and the discharge of lime and soda takes place into a dilution tank fitted below. The measured lime and soda emulsion is diluted in this tank by soft water, and the diluted mixture is pumped continuously to the raw water inlet point on top of the softener by means of a specially constructed reciprocating pump which is mounted on the side of the lime and soda tank.

The arrangement of this measuring gear is such that dosage is always proportionate, since if the flow of water to the plant dimin-

ishes, a reduction occurs in the number of meter contacts, and consequently the number of valve discharges is correspondingly reduced. Conversely, if an increase in flow occurs, the valve is opened more frequently to cope with the increase. Alongside the lime and soda storage tank there is mounted a lime slaking tank measuring 9 ft. diam. by 3 ft. 9 in. deep and an auxiliary measuring equipment is also provided for the addition of a coagulant, sodium aluminate. The hard water and the measured chemicals enter the settling tank by way of the downtake pipe, which reaches from the top of the settling tank to a point within the sludge collecting cone at the base of the tank, and agitating gear is fitted to ensure even mixing and to accelerate flocculation. On reaching the base of the downtake, the water begins to rise slowly in the tank towards a wood wool filter. The filter effects final clarification, and the accumulated sludge in the sedimentation tank is discharged from the cone bottom at the required period.

Beneath the base of the settling tank, there is provided a reinforced concrete sludge pit into which the sludge is discharged and settled, and a floating arm is arranged for the draw-off of the resulting clear water. Thickened sludge is pumped through a filter press installed within the housing which appears to the left of the settling tank in the first of the accompanying illustrations. The use of the filter press considerably simplifies the disposal of the sludge, since by its use the liquid sludge is converted into sludge cakes which can readily be handled and transported.

[621. 45 & 656. 222.1]

5. — Railcar acceleration.

by Dipl.-Ing. J. L. KOFFMAN,

(Diesel Railway Traction, Supplement to *The Railway Gazette*).

The rapid advance of the diesel railcar has brought both designers and operators face to face with numerous problems which, although forming the subject of wide discussions along rather general lines, are sometimes not given

sufficiently close attention to enable exact calculations of the necessary limits of the application and the resulting first costs and maintenance expenses to be based upon the facts. Among these problems the question of power

transmission and power-weight ratio with high-speed railcars deserves serious consideration.

Mechanical transmission has forged ahead for use in engines developing up to 500 B.H.P. While a power-weight ratio of about 10 B.H.P. per ton is recommended for modern acceleration and maximum speed requirements, it is not always possible to obtain this ratio within the given weight and price limits. In order to determine the influence of power-weight ratio upon the operating characteristics of a high-speed railcar, performance curves were plotted from recent trials with an articulated vehicle on the Continent, and the results obtained are here applied to a similar vehicle for which different engines were available.

In design and appearance the car resembles the latest vehicles of the Flying Hamburger type and weighs 90 tons. Both the end bogies carry a power plant consisting of an engine and five-speed mechanical transmission driving both axles through bevel gears. An articulated bogie carries the inner ends of the two bodies. The wheels are of 2 ft. 11 1/2 in. in diameter and owing to existing track conditions the maximum speed has been limited to 81 m.p.h. Five different types of engine were available for consideration, the main data concerning them being summarised in the accompanying table.

A Mylius pre-selective pneumatically operated transmission of the GW type (as fully described in our issue of July 9, 1937) is assumed, the gear ratios being 4.74, 2.66, 1.38,

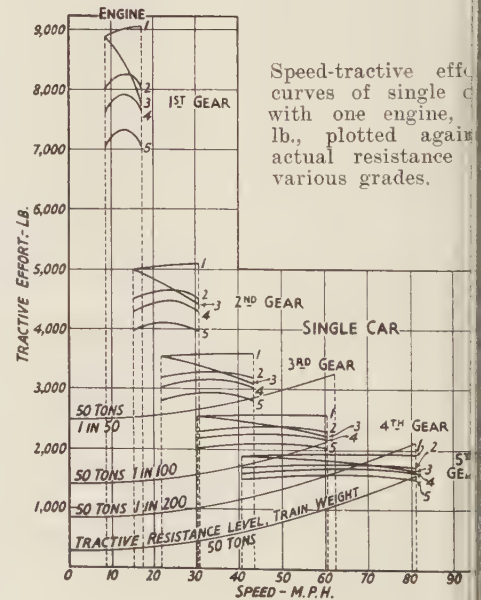
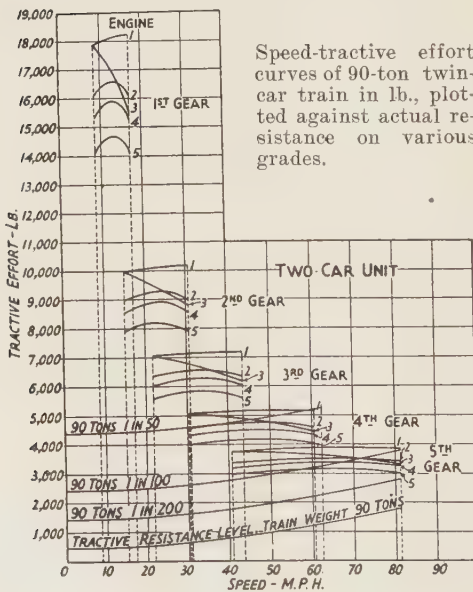
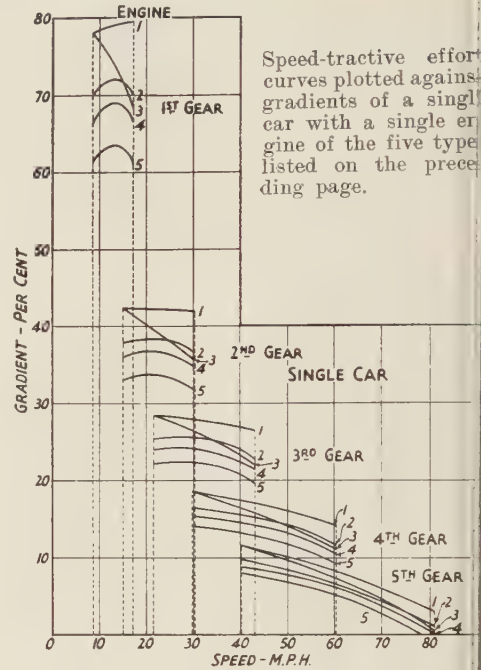
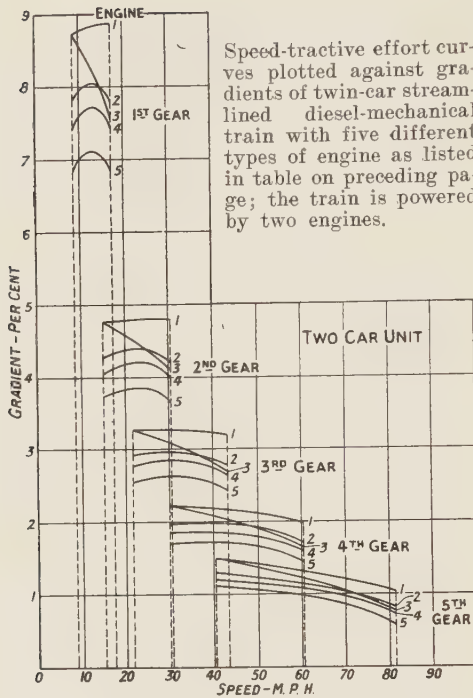
1.342, and 1 to 1. An assumed total efficiency of power transmission from engine to axle of 94 per cent. was taken into account in preparing the curves, while a further allowance of 19, 4.5, and 2.5 B.H.P. per engine was made for the radiator fans, air compressor, and lighting dynamos respectively. The tractive effort required for the propulsion of the car has been calculated on the assumption that the frontal area of the car is 75.5 sq. ft.

Speed-tractive effort characteristics.

The speed-tractive effort shows that while any one of the five engines can maintain maximum speed on the level and up an incline of 1 in 200, leaving ample power for acceleration, only the Daimler (Mercedes) model provides sufficient power to negotiate a gradient twice as steep at almost maximum speed, while a speed of about 60 m.p.h. can be maintained in fourth gear on an incline of 1 in 50. The other four engines develop only about 43 m.p.h. in third gear over the same gradient. It is of interest to note that apart from the Maybach engine, the torque characteristics of the engines in question are comparatively constant and parallel to each other over the whole speed range. With the 410-B.H.P. Maybach engine the torque at low speed has the same value as the 475-B.H.P. Daimler power unit running at the same speed, but at full engine speed it drops by about 12 per cent., a desirable set of characteristics for starting up on heavy gradients. The speed-gradient performance curves also show that with the exception of the M.A.N.

ENGINE TYPES AVAILABLE.

Make.	Type.	H.P.	R.p.m.	Weight, lb.	No. of cyls.	Bore, mm.	Stroke, mm.	Fuel consumption at full load in gts. per B.H.P.-hr.	Power/weight ratio, H.P. per ton.
Daimler-Benz OM86 . .	Vee	475	1 400	5 250	16	165	195	210	10.5
M.A.N. 412 V	Vee	420	1 400	6 400	12	175	180	173	9.3
Maybach GO56. . . .	Vee	410	1 400	4 625	12	160	200	170	9.1
Paxman Comet MKIII .	Vee	400	1 500	—	12	177.8	196.85	165	8.9
Ganz	Vertical	370	1 300	6 700	8	170	240	163	8.2



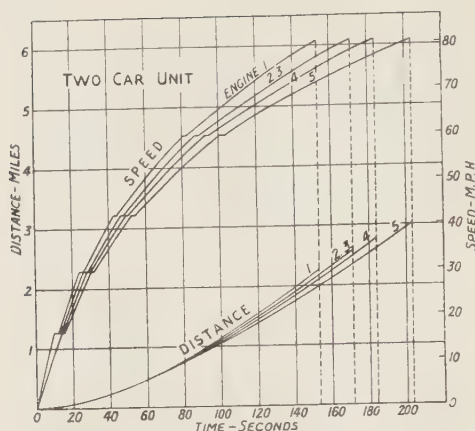
engines, none is able to drive the car over a gradient of 1 in 33.3 at a speed of 43 m.p.h. on the top of third gear, while on an incline of 1 in 25 (which is sometimes found on foreign lines) all but the 370-B.H.P. engines are able to maintain a speed of 30 m.p.h. or so in second gear.

It is evident that while the power-weight ratio is not of such great importance for operation over level track, even a small incline of 1 in 100 makes a considerable difference. As may be seen on the gradient-speed diagram, full speed on such a gradient can be achieved only with two 475-B.H.P. engines, as against 2 m.p.h. for both 420 and 410-B.H.P. engines and round about 60 m.p.h. with the 370-B.H.P. units. When considering the type of engine to be employed the nature of the service for which they are destined is also of importance. Whereas both the 420-B.H.P. engines can attain maximum speed in 2 min. 33 sec., on level track, the 375-B.H.P. models require 3 min. 23 sec. over a long-distance non-stop run of, say, 100 miles, covered at an average speed of 60 m.p.h., the difference in running time due to slower acceleration with the 370-B.H.P. engines would amount to only 0.6 per cent., rising to 9 per cent. for a service involving a stop every 10 miles. This can be made good by reducing the waiting time without perceptibly increasing gross fuel consumption due to the reduced consumption of the smaller engines. However, the possibilities offered of compensating for the lack of acceleration by running longer periods under power are limited by the type of service in question. It is of interest to note that, allowing 2 sec. lost per gear change, or 10 sec. for the five-speed gears, 7.2 and 4.9 per cent. of time is lost in acceleration with the 475-B.H.P. and 370-B.H.P. engines respectively, and a transmission with a sustained drive would be of definite advantage. Fuel costs being between 13 and 16 per cent. of the total operating expenditure (the average being about 15 per cent.), the 22.5 per cent. reduction in fuel consumption of the Ganz engine as compared with the M.A.N. unit permits a 3.4 per cent. reduction in operating costs for almost equal performance for long-distance service.

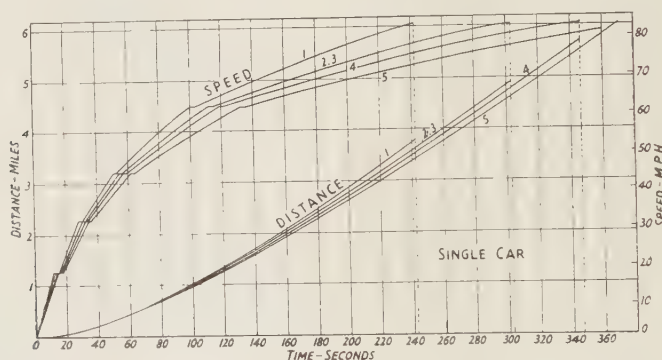
The influence of the available power output becomes far more pronounced with a single-engined vehicle, as is shown by curves plotted for a 50-ton unit powered by one of the engines considered with the articulated car, employing similar gear and allowing the same amount of power for auxiliary drives. At full car speed the tractive resistance on the level is increased from 19.5 lb. per ton, as with the articulated car, to 31.5 lb. per ton due to the influence of air resistance, which, with the same front surface becomes more pronounced per ton of weight with a light vehicle than with a heavy one. On this account the 370-B.H.P. engine is not in this case considered, as its maximum speed is limited to about 80 m.p.h. The 475-B.H.P. engine attains its maximum speed in 4 min. 2 sec., as against 5 min. 46 sec. for the 400-B.H.P. unit, the average rate of acceleration being 0.33 m.p.h. p.s. as compared with 0.23 m.p.h. p.s. respectively. The difference in performance is again not of great importance for long-distance non-stop service, but deserves careful consideration for short-distance service, especially when operation is over lines with frequent gradients, when an increase of engine power output from 400 to 475 B.H.P. would considerably improve the operation performance of the vehicle.

Besides being limited by the available power output the rate of acceleration is also limited by adhesion. It is well known that the coefficient of adhesion between wheel and rail is reduced with the increase of speed and that it depends to a considerable extent on the conditions of wheel and rail. Thus high values are shown with clean, dry rails, somewhat reduced values with wet rails, and a considerable reduction is noticeable in rainy or foggy weather. It is also known that adhesion is reduced when rolling is replaced by gliding, as when starting up on curves, in which case pure rolling cannot be achieved with both wheels fixed on a common axle. It is, however, not known whether the adhesion depends on the axle load or wheel diameter.

At present, dependable data on the value of the coefficient of adhesion are available for speeds up to 50 m.p.h., indicating that in starting on dry rails with efficient sanding, a value



Acceleration curves on distance and time bases of twin-car diesel-mechanical train powered by two engines of the types listed in table.



Acceleration curves of single car with one engine of the types listed.

of 33 per cent. can be obtained as against 25 per cent. on wet rails, this value gradually diminishing to 18 per cent, and 12 per cent, at 50 m.p.h. This clearly indicates the necessity for increasing the adhesion weight by driving a greater number of axles, in order to ensure good accelerating qualities, especially when starting up on gradients.

The curves of car acceleration also show that while the increase of speed is similar with all engines in the lower gears, it is the performance above third gear that is of paramount importance. A slight change in the slope of the curve results in considerable alteration in the time required for acceleration up to full speed. It is evident from this that ample power must be available not only for quick acceleration at starting but also at higher speeds, in order to attain maximum speed. This is particularly so when frequent slacks are made due to existing track conditions, thus improving the car performance. The importance of this point was not recognised until comparatively recently.

It is to be hoped that the foregoing remarks will give an idea of the value of comparative railcar performance curves in clearing up most of the basic problems involved when consider-

ing the effects gained from railcar operation over certain routes. It is also to be hoped that similar curves will be prepared in future to the benefit of both manufacturers and operators who are contemplating the introduction of railcars, as the question of first cost and maintenance expenses is also involved.

[625. 215 (.75), 625. 215 (.75) & 625. 232 (.73)]

6. — New pendulum-type cars tested.

Articulated two-car unit, built in California, embodies unique principles of design.

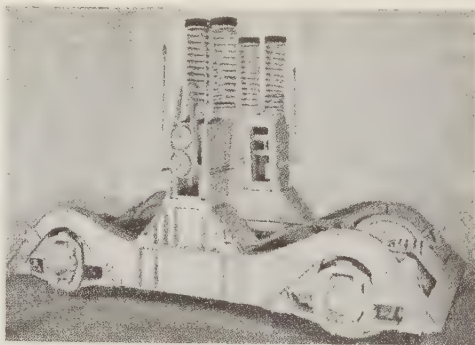
(Railway Age.)

With a view to providing minimum weight for economy, low center of gravity, large design factors of safety and smooth riding on existing track, a new « pendulum » type of passenger car has recently been designed and an articulated two-car unit built and placed in test service on the Atchison, Topeka & Santa Fe Harbor district lines near Los Angeles, Calif. Development work on this equipment has been sponsored by C. T. Hill, son of Louis W. Hill, retired chairman of the Great Northern. The Santa Fe has co-operated to the extent of providing motive power and testing facilities. Principal interest in the new design centers about the suspension system, or method of mounting the car on the truck which departs completely from standard practice. The car body is virtually suspended from the truck, operating on soft vertical coil springs in a plane above the center of gravity of the body. These springs permit, through horizontal deflection, and the necessary truck motion relative to the body, this motion being positioned and controlled by a pair of horizontal links, elastically restrained by rubber, acting between the body and the truck frame at a height well above the body center of gravity.

General description of experimental unit.

The principal springing of the body being above the center of gravity, may be as soft as desired, and any tendency for body roll on curves is in the direction to correct for uncompensated side force on curves. This action « bank » is in direct contrast to the behavior of a standard car and truck leaning outwardly on curves insufficiently superelevated. Likewise, the lateral restraint of the car body by this new suspension system may be designed for as low a frequency as required, since action is not restricted as in a standard truck by swing hanger length and possible

bolster travel. For both the vertical and lateral motions, simple shock absorbers are applied to dampen resonance or harmonic oscillation.



Fabricated steel truck which is designed to support the car body above the center of gravity and provide a pendulum motion, rubber-cushioned and controlled.

The experimental unit, illustrated, consists of two bodies suspended from three trucks, the center truck forming an articulated connection between the bodies.

Outside views convey the erroneous impression that the cars are small. However, the maximum inside width of 9 ft. 9 in. is several inches greater than many standard cars. In spite of a low overall height of 11 ft., an adequate inside height of 8 ft 2 1/2 in. is made possible by a 30-in. floor level. The truck suspension structure is housed by well-insulated pockets within the body. The overall length of the front body is 70 ft. and that of the rear body is 79 ft. Since the gross weight of the articulated vehicle is only 65 000 lb., wheel loads are low.

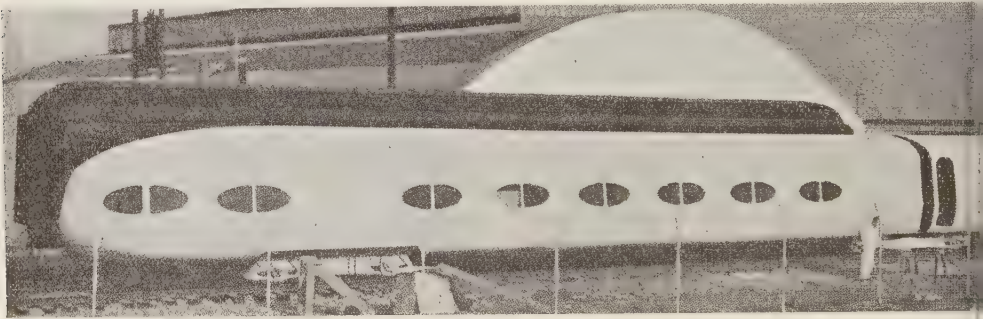
The front end of the front car is fitted with a special drawbar to attach to a standard six-

wheel-truck club car. A raised platform in the front test unit allows easy passage into the standard car. The tail end of the rear unit has an overhang of 19 ft. from the center of the rear truck. The center of gravity of the entire car is approximately 45 in. above the rails.

The truck itself is a substantial structure, fabricated of low-gage high-tensile steel arc-welded and stress-relieved. The truck frame rests on semi-elliptic springs carried by journal-box hangers, which in turn are supported on rubber shear pads on the journal boxes to permit a small transverse movement of the

been made separable so that cars articulated at both ends can be uncoupled and switched to provide flexibility in train make-up. The Bethlehem rolled-steel wheels have cylindrical treads and a diameter of 30 in. Axles are hollow-bored and are fitted with Fafnir ball bearing journals.

A standard clasp-brake system is employed, operated by Westinghouse air-brake equipment. On the end trucks one air cylinder operates the shoes on all four wheels through a simple, fully equalized linkage; each half of the articulated truck has its own brake system with an air cylinder operating the shoes on two



The rear body of a two-unit articulated « pendulum » type car which incorporated unique features of construction.

axles. Since in service there are no moving metallic contacts or sliding surfaces where wear or play can develop, the wheels, axles, bearings and frame are relieved of heavy shock and impact loads. Brake thrust, but not torque, is carried by the leaf spring which has been designed for this duty. The entire journal assembly is provided with guard flanges made like a loose pedestal guide to confine the journal box in the event of failure of rubber parts or springs.

Details of the truck design.

The end trucks have a 9-ft. wheelbase. A 12-ft. wheelbase for the articulating truck is possible because the load from the body is carried directly over each axle and thus the frame is subjected to no bending moments due to body load. The articulating truck frame has

wheels. A simple method of automatic slack adjustment is provided. The total weight of each 9-ft. full truck, completely equipped, is 8 800 lb., and the 12-ft. articulated truck weighs 10 900 lb.

How the suspension system works.

The truck view shows two towers bolted rigidly to the truck frame proper so that the towers function as a unit; however, for removal of the truck from the car, the towers may remain suspended within the body pockets so that the body need not be raised to an excessive height. The coil springs mounted on the towers carry the body with a static deflection of about 8 1/2 in., which is much softer springing than is usually provided for railroad cars. These springs are specially designed to allow lateral as well as axial movement. The rubber

ushioned lateral restraint arm seen on the side of the tower connects to the body through a link located at a level about 20 in. above the center of gravity of the car body proper. This lateral control system is designed to furnish a soft restraint at the center of its range and stiffen gradually as it is deflected by sustained side load. Longitudinal positioning of the truck is accomplished by a tubular draft link interconnecting and attached to both the truck and body by means of a new type of rubber buffer; these buffers allow the required angular movement of the link and also provide cushioning for buff or draft loads. At the articulated truck, these links carry the main draft load and at the full trucks they take only braking and inertia loads.

The truck design described incorporates no working joints carrying body loads nor are there any points where slack or wear can develop. These parts replace swing hangers, spring plank, bolster springs, bolster, bolster wear plates, center plate and side bearings in the usual truck construction. The Delco hydraulic shock absorbers seen on the sides of the towers attach to the body through the long vertical links and serve to damp vertical and banking motions. On the top of each tower is seen one hydraulic shock absorber connected to the lateral restraint arm.

To assist in achieving the objective of light weight, the body structure is also a radical departure from conventional practice, embodying a stressed-skin or semi-monocoque (*) body

structure, with an outer covering of Douglas fir plywood. A static load test to twice the normal gross load is said to have proved the strength and rigidity of these car bodies, which are also entirely free of the creaks and groans usually associated with wooden structures. Wood was used in the test cars merely as a convenient expedient in arriving at suitable means to test the trucks and suspension structure within a reasonable time and at a reasonable cost. The car bodies are thus definitely temporary in contrast to the trucks which have been engineered for permanent service. Monocoque construction is adaptable to a variety of materials and a design using the recently developed high-tensile steels is under way for future cars. The trucks of the test train are built to carry such steel bodies.

Preliminary test results.

Road tests of this new train unit are now in progress and indicate a substantial improvement in passenger comfort. Standing and walking about is said to be accomplished with greater ease and with a feeling of greater stability than in a standard six-wheel-truck club car, weighing six times as much as one of the new cars. Writing at a table is said to be distinctly easier and the result more legible than when done in a standard car. This improvement in riding quality is credited to the absence of the harsh lateral acceleration characteristic of standard equipment at high speeds on indifferent track.

Further test runs including a variety of track conditions are to be made to establish ranges of control, both lateral and vertical, as well as to study the degree of comfort introduced by correct body roll or bank on curves.

(*) The term « monocoque » applies to a type of airplane construction in which the fuselage is built by wrapping wood veneer around forms, in which the veneer is primarily depended on to carry the stresses.

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

International Railway Congress Association

Meeting of the Permanent Commission, held on the 9th July, 1938.

The Permanent Commission of the International Railway Congress Association met on the 9th July last in the *Jules Jadot* room of the Belgian National Railways Head Offices, at Brussels.

* * *

Mr. RULOT, *President*, on opening the meeting, paid a tribute to the memory of Mr. TONDELIER, former President of the Permanent Commission (1913 to 1925), who died on the 9th March, 1938, at the age of 87.

Mr. TONDELIER who resigned the Presidency at the time of his retirement as General Manager of the Belgian State Railways, in 1925, had rendered the greatest services to the Association.

The President also acquainted the Meeting with the death of Mr. Douglas VICKERS, Director, London Midland and Scottish Railway, and member of the Executive Committee of the Association since 1934, of Mr. CAUFRIEZ, Honorary General Manager of the Belgian National Light Railways Company, and member of the Permanent Commission from 1922 to 1933, and finally of Dr. HEROLD, late

Manager of the third Division of the Swiss Federal Railways, who was a member of the Permanent Commission from 1922 to 1926.

The various points on the agenda were then dealt with.

The President recalled article 9 of the Rules and Regulations, stating that : « At its first Meeting after a Congress, the Permanent Commission shall nominate three of its members, who, with the President and Vice-Presidents of the Commission, shall form an Executive Committee ».

As the Permanent Commission had not met since the Paris Congress, in 1937, this formality had now to be complied with.

The Executive Committee was consequently made up as follows :

President : Mr. RULOT.

Vice-Presidents : MESSRS. LAMALLE and LE BESNERAIS.

Members : Mr. GRIMPRET, Lord ROCKLEY and Sir Ralph WEDGWOOD, Mr. GHILAIN, *general Secretary* of the Association, acting as Secretary to the Committee.

The Permanent Commission then appointed several members to take the place of those who resigned or died.

The following Gentlemen were elected :

Mr. Harold MACMILLAN, Director, Great Western Railway;

Mr. DAHLBECK, General Manager, Swedish State Railways;

Mr. J. LÉVY, Chief Mechanical Engineer, French National Railways Company;

Mr. CLAUDON, Councillor of State, General Manager of the Railway and Transport Department at the French Ministry of Public Works;

Sir Leonard BROWETT, Permanent Secretary of the British Ministry of Transport;

Mr. H. ETTER, General Manager of the Swiss Federal Railways;

Mr. NACHTERGAELE, Manager of the Operating Department, Belgian National Railways Company;

Mr. J. H. NUELLE, President, Delaware and Hudson Railroad;

Mr. LANER DE ORSAVA, Ministerial Head of Section, President, Royal Hungarian State Railways,

to take the place of Messrs. CADOGAN, GRANHOLM, HENRY-GRÉARD, GUFFLET, Sir Cyril HURCOMB, Messrs. SCHRAFL, JADOT, BREE and DE SENN respectively, who had resigned (Art. 6 of the Rules and Regulations).

Furthermore, Sir Harold HARTLEY, Vice President, London Midland and Scottish Railway, was appointed to replace the late Mr. VICKERS, and Don Manuel M. Garcia TORRE, General Manager of the Railway Department at the Ministry of Public Works of the Argentine

Republic, was made a supplementary member for Argentina.

* * *

The statements of receipts and expenditure for the year 1937, which had been audited and found quite accurate by a chartered accountant, were approved by the Meeting.

The provisional budget drawn up for the year 1938 was also laid before the members of the Permanent Commission, who found, after examination of this statement, that by the end of the present year, the financial position will remain quite satisfactory.

Consequently, it was decided that the rate of the variable part of the yearly contribution will remain 0.08 gold-franc per kilometre for the year 1939, the maximum rate laid down by the Rules and Regulations (Art. 17*b*) being 0.20 gold-franc per kilometre.

* * *

Mr. BARRIOL then read the report, drawn up by Sir Nigel GRESLEY and himself, on the verification undertaken by them of the accounts of the International Railway Congress Association for the period from January 1st, 1934, to December 31st, 1937 (Accounts of the 13th Session); this report was approved.

* * *

Acting on the suggestion of the President, the Permanent Commission decided to hold an enlarged meeting of the Commission, in Brussels, in July 1939.

As was done in July 1933, the Permanent Commission will discuss two questions of general interest to the members of the Association.

The two questions are worded as follows :

I. Methods used to speed up passenger trains, and the resulting expenditure.

In particular, operating by means of railcars, and the financial results obtained by this method.

II. How should the problems of simplifying the working be considered in the future in the interest both of the public and of the railways?

It was decided that the first question will be reported upon by French, British and German railway officers, and the second question dealt with by a French, a Belgian, and an Italian reporter.

Two French reporters are already appointed :

Mr. DUMAS, Manager, Technical Organisation Department, French National Railways Company, for *Question I*, and

Mr. GOURSAT, Manager, Traffic Department, of the same Company, for *Question II*.

It was agreed that the other reporters would be appointed without delay (*).

(*) Since the meeting held on July 9th, 1938, by the Permanent Commission, the other reporters have also been appointed, namely :

Question I :

Mr. T. W. ROYLE, M. B. E., Chief Operating Manager, London Midland and Scottish Railway;

Mr. F. E. HARRISON, Engineer, North Eastern Area, London & North Eastern Railway;

Mr. STROEBE, Reichsbahndirektor, Deutsche Reichsbahn;

Mr. ROHDE, Direktor bei der Reichsbahn, Deutsche Reichsbahn;

Mr. EBERT, Reichsbahnoberrat, Deutsche Reichsbahn.

Question II :

Dr. Gr. Uff. Pietro LO BALBO, president, « Società Anonima Tramvia Dogliani-Monchiero »;

Mr. DESORGHER, Technical Secretary, General Management of the Belgian National Railways Company.

The Railways will be distributed as follows between the reporters.

Question I :

British reporter : English speaking countries;

German reporter : Germany and Central European countries;

French reporter : All other continental countries.

Question II :

French reporter : Continental main-line railways, except Belgium;

Belgian reporter : English speaking countries and Belgium;

Italian reporter : Secondary railways.

It was decided that the Secretariat would at once communicate with the appointed officers, to make it possible to publish the reports in the *Bulletin of the Association* (English, French and German editions) and distribute same to the members of the Permanent Commission before the July 1939 meeting. It was also decided that, as in 1935, members of the Permanent Commission will be assisted, for the discussion of these questions, by highly-placed officials or technicians of their respective Railways.

* * *

The General Secretary acquainted the Meeting with the changes which occurred in the membership of the Association since the previous meeting :

The Central Office for International Transport by railway, Berne, has joined the Association; its yearly contribution is 100 gold-francs.

The French National Railways Company, which took over the operation of the seven French main-line Systems, has also become a member 42 475 km. (26 393 miles)

The following Railways also joined the Association :

The « Compagnie franco-polonaise de chemins de fer » (headquarters in Paris) 465 » (289 »)

The « Compagnie des Chemins de fer du Sud-Ouest » (30, Place de la Madeleine, Paris) which had resigned in 1936. 407 » (253 »)

H. E. H. The Nizam's State Railway (India) 2 174 » (1 351 »)

Total 45 521 km. (28 286 miles)

On the other hand, it was noted that :

(1) As the Austrian railways have been operated since the 18th March, 1938, by the Deutsche Reichsbahn, this Administration now works 60 353 km. (37 502 miles) of lines instead of 54 556 km. (33 900 miles).

(2) As from the 1st January, 1938, the

lines of the Netherlands State Railways Company and the Holland Railway Company have been amalgamated and are worked by the General Management of the Netherlands Railways Company.

The following resignations have been received since the last Meeting of the Permanent Commission :

Nord Railway (France) 3 922 km. (2 437 miles)

Est Railway (France). 5 132 » (3 189 »)

State Railways (France) 9 665 » (6 006 »)

Paris-Orléans Railway (France) 7 408 » (4 603 »)

Paris-Lyon-Méditerranée Railways (France) 9 948 » (6 181 »)

Midi Railways (France) 4 340 » (2 678 »)

Alsace-Lorraine Railways (France) 2 095 » (1 302 »)

These seven railways now make up the French National Railways Company's system.

Have also given up membership :

Taltal Railway Company (Chile) 264 » (164 »)

Nitrate Railways (Chile). 664 » (413 »)

Compagnie des Tramways départementaux des Deux-Sèvres 198 » (123 »)

Compagnie des Tramways de l'Indre. 182 » (113 »)

Salvador Railway. 161 » (100 »)

Total 43 949 km. (27 310 miles)

These alterations in the membership result in :

an increase of one organisation;

a decrease of 10 railways;

an increase of about 500 km. (310 miles), besides an increase of about 1 000 km. (620 miles) resulting from the total mileage extension of the systems represented at the Association.

The latter is now made up of 185 railway systems, working on the aggregate 537 754 km. (334 151 miles) of lines.

The President stated that the Secretariat would soon communicate with the members of the Permanent Commission and the participating Administrations, requesting them to send their suggestions as regards the questions to be placed on the Agenda of the Berlin Congress (1941).

This agenda will be laid before the meeting of the Permanent Commission in July 1939.

P. GHILAIN,
General Secretary.

N. RULOT,
President.

List of Members of the Permanent Commission

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(July 9th, 1938).

President :

Rulot ⁽²⁾, directeur général de la Société Nationale des Chemins de fer belges ; 231, rue Royale, Brussels.

Vice-Presidents :

Lamalle ⁽¹⁾, directeur général adjoint de la Société Nationale des Chemins de fer belges ; 17, rue de Louvain, Brussels ;

Besnerais ⁽³⁾, directeur général de la Société Nationale des Chemins de fer français ; 88, rue Saint-Lazare, Paris.

Members of the Executive Committee :

Impret ⁽¹⁾, conseiller d'Etat, vice-président du Conseil général des Ponts et Chaussées, vice-président de la Société Nationale des Chemins de fer français ; Paris ;

Right Hon. Lord Rockley ⁽³⁾, P. C., G. B. E., director, Southern Railway ; 2, Cadogan Square, London S. W. 1 ;

Ralph Lewis Wedgwood ⁽³⁾, CB., C.M.G., chief general manager, London & North Eastern Railway ; King's Cross Station, London, N. 1.

Ex-presidents of session, members ex-officio :

Ibrahim Fahmy Kerim Pasha ; Cairo ;
Edouard de Rothschild, président du conseil d'administration de la Compagnie du chemin de fer du Nord français ; Paris.

Members :

Sir Leonard Browett ⁽³⁾, K. C. B., permanent secretary of the Ministry of Transport (Great Britain) ; Northumberland Avenue, London W. C. 2 ;

J. Castiau ⁽¹⁾, secrétaire général du Ministère des Transports de Belgique ; 17a, rue de la Loi, Brussels ;

H. E. Mahmoud Chaker Pasha ⁽²⁾, under-secretary of State, General Manager of the Egyptian State Railways ; Cairo ;

Claudon ⁽²⁾, conseiller d'Etat, directeur général des Chemins de fer et des Transports au Ministère des Travaux publics ; 244, boulevard Saint-Germain, Paris ;

M. W. Clement ⁽³⁾, president, Pennsylvania Railroad ; Broad Street Station, Philadelphia ;

R. da Costa Couvreur ⁽³⁾, ingénieur, inspecteur, secrétaire général au Ministère des Travaux publics et des Communications du Portugal ; Avenida Antonio de Serpa, 2-3º, Lisbon ;

G. O. W. P. Dahlbeck ⁽¹⁾, directeur général et chef des Chemins de fer de l'Etat suédois ; Stockholm ;

Dautry ⁽²⁾, administrateur de la Société Nationale des Chemins de fer français ; 88, rue Saint-Lazare, Paris (IX^e) ;

Sir Francis Dent ⁽²⁾, C. V. O., director, Southern Railway (Great Britain) ; Dock House, Beaulieu (Hants), England ;

Baron Edouard de Rothschild (already named) ;

Retires at the 14th session.
Retires at the 15th session.
Retires at the 16th session.

- de Ruffi de Pontevès** ⁽¹⁾, inspecteur général des mines, directeur du contrôle du travail des agents de chemin de fer, Ministère des Travaux publics; Paris;
- de Spirlet** ⁽²⁾, inspecteur général des Chemins de fer du Nord belge; Liège;
- Dr. Ing. eh. **J. Dormmüller** ⁽³⁾, Minister of Communications, General Manager of the German State Railways; 35, Voss-Strasse, Berlin W. 8;
- H. Etter** ⁽¹⁾, président de la Direction générale des Chemins de fer fédéraux suisses; Berne;
- F. Fiori** ⁽³⁾, ingénieur, conseiller d'administration des Chemins de fer de l'Etat italien; Villa Patrizi, Rome;
- Sir Henry **Fowler** ⁽¹⁾, K. B. E.; Spondon Hall, near Derby;
- P. Ghilain** ⁽¹⁾, ingénieur en chef au Service du Matériel de la Société Nationale des Chemins de fer belges; 231, rue Royale, Brussels;
- Sir H. Nigel **Gresley** ⁽¹⁾, C. B. E., D. Sc., chief mechanical engineer, London & North Eastern Railway; King's Cross Station, London, N. 1;
- Grimpret** (already named);
- Sir Harold **Hartley** ⁽²⁾, vice-president, London Midland & Scottish Railway; Euston Station, London, N. W. 1;
- R. J. Harvey** ⁽²⁾, consulting engineer to the Government of New-Zealand; 34, Victoria Street, Westminster, London, S. W. 1;
- Masaru **Iwamura** ⁽¹⁾, secretary of the Japanese Ministry of Railways, Manager of the Berlin Office; 11, von der Heydt Strasse, Berlin, W. 35;
- L. Jacobs** ⁽³⁾, directeur général de la Société Nationale belge des Chemins de fer Vicinaux; 14, rue de la Science, Brussels;
- H. Jezierski** ⁽³⁾, conseiller ministériel au Ministère des Communications de Pologne; Warsaw;
- E. Kejr** ⁽²⁾, ingénieur, conseiller ministériel, chef du département V/5 au Ministère des Chemins de fer de Tchécoslovaquie; Prague;
- H. E. Ibrahim Fahmy Kerim Pasha** (already named);
- J. H. Kirkness** ⁽²⁾, secretary to the Railway Board (India); Little Kenwyn, Liphook (Hants), England.
- Dr. Th. **Kittel** ⁽¹⁾, Reichsbahndirektor, Deutsche Reichsbahn; 35, Voss-Strasse, Berlin, W. 8;
- P. Knutzen** ⁽²⁾, directeur général des Chemins de fer de l'Etat danois; 40, Sölvgade, Copenhagen, K.;
- Kradolfer** ⁽³⁾, directeur de l'Office fédéral des Transports de la Confédération suisse; Berne;
- U. Lamalle** (already named);
- C. Lâner de Orsova** ⁽³⁾, chef de section ministériel, président de la Direction des Chemins de fer royaux de l'Etat hongrois; 73, Andrássy út, Budapest VI;
- R. Le Besnerais** (already named);
- C. Lemaire** ⁽³⁾, directeur du Service de la Voie de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Brussels;
- J. Lévy** ⁽²⁾, ingénieur en chef, directeur du Service central du Matériel de la Société Nationale des Chemins de fer français; 20, rue de Rome, Paris;
- H. Macmillan** ⁽¹⁾, M. P., director, Great Western Railway; Messrs. Macmillan & Co. Ltd., St Martin's Street, London, W. C. 2;
- Ion Macovei** ⁽¹⁾, ingénieur, inspecteur général, directeur général des Chemins de fer de l'Etat roumain; Bucharest;
- A. Mange** ⁽³⁾, administrateur de la Compagnie du Chemin de fer de Paris à Orléans, président du Comité de gérance de l'Union internationale des Chemins de fer; 42, rue de la Bienfaisance, Paris;

⁽¹⁾ Retires at the 14th session.

⁽²⁾ Retires at the 15th session.

⁽³⁾ Retires at the 16th session.

- Marguerat** ⁽³⁾, directeur des Compagnies de Chemins de fer de Viège à Zermatt, Furka-Oberalp, Gornergrat et Schöllenen; Lausanne;
- Maristany** ⁽²⁾, marquis d'Argentera, directeur général de la Compagnie des Chemins de fer de Madrid à Saragosse et à Alicante; Estación de Atocha, Madrid;
- Moralès** ⁽¹⁾, vice-président du Conseil supérieur des Chemins de fer d'Espagne, président du Conseil d'administration des Chemins de fer de l'Ouest de l'Espagne; Estación de las Delicias, Madrid;
- Moreno Ossorio** ⁽³⁾, administrateur à la Commission permanente du Comité exécutif des Chemins de fer du Nord de l'Espagne; Estación del Norte, Madrid;
- Mugniot** ⁽²⁾, directeur attaché à la direction générale de la Société Nationale des Chemins de fer français; 88, rue Saint-Lazare, Paris (IX^e);
- Nachtergaele** ⁽³⁾, directeur du Service de l'Exploitation de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Brussels;
- Nobili** ⁽²⁾, ingénieur, vice-directeur général des Chemins de fer de l'Etat italien; Rome;
- H. Nuelle** ⁽²⁾, president, Delaware & Hudson Railroad; 32, Nassau Street, New York City;
- Ottone** ⁽³⁾, président de la Federazione Nazionale Fascista degli Esercenti Imprese Ferroviarie, Tramviarie e di Navigazione interna; 115, Piazza Montecitorio, Rome;
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- J. Pelley** ⁽²⁾, president, Association of American Railroads; Transportation Building, Washington D. C.;
- C. Ramallo** ⁽¹⁾, ingénieur, director del Instituto de Economia de los Transportes, Facultad Nacional de Ciencias Económicas; Buenos Aires;
- The Right Hon. Lord **Rockley**, P. C., G. B. E. (already named);
- N. Rulot** (already named);
- Dr. **Sauer** ⁽³⁾, Ministerialrat, Reichsverkehrsministerium; 80, Wilhelmstrasse, Berlin W. 8;
- G. Sgoureff** ⁽¹⁾, ingénieur, directeur général adjoint des Chemins de fer et des Ports de l'Etat bulgare; Sofia;
- Lord **Stamp** ⁽¹⁾, G. C. B., G. B. E., D. Sc., chairman and president of the Executive, London Midland & Scottish Railway; Euston Station, London N. W. 1;
- Surleau** ⁽¹⁾, directeur général adjoint de la Société Nationale des Chemins de fer français; 88, rue Saint-Lazare, Paris (IX^e);
- T. C. Swallow** ⁽²⁾, advisory engineer, Office of the High Commissioner for the Union of South Africa; South Africa House, Trafalgar Square, London, W. C. 2;
- R. E. Thomas**, chief inspecting engineer (Egyptian Government); London;
- Don Manuel M. Garcia **Torre** ⁽³⁾, ingénieur directeur général des Chemins de fer au Ministère des Travaux publics de la République Argentine; Buenos-Aires;
- Antonio **Valenciano y Mazerès** ⁽¹⁾, inspecteur général des Ponts et Chaussées, administrateur de la Compagnie des Chemins de fer de Madrid à Saragosse et à Alicante; 5-3^o, General Oraâ, Madrid;
- H. van Manen** ⁽³⁾, directeur général des Chemins de fer néerlandais, S. A.; Utrecht;
- Th. M. B. **van Marle** ⁽²⁾, inspecteur-generaal van het Verkeer, Rijksverkeersinspectie; The Hague;

(3) Retires at the 14th session.

(2) Retires at the 15th session.

(1) Retires at the 16th session.

L. **Velani** ⁽³⁾, directeur général des Chemins de fer de l'Etat italien; Villa Patrizi, Rome;

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D. **Willard** ⁽³⁾, chairman of the Board, Association of American Railroads; president, Baltimore & Ohio Railroad; Baltimore, Md.;

M. **Yoyitch** ⁽¹⁾, directeur général adjoint des Chemins de fer de l'Etat yougoslave; Belgrade;

N... ⁽³⁾ (Brazil);

N... ⁽²⁾ (Egypt);

N... ⁽¹⁾ (Germany);

N... ⁽²⁾ (Germany);

N... ⁽²⁾ (Germany).

Honorary member: C. **Colson**, membre de l'Institut, inspecteur général des Ponts et Chaussées, vice-président honoraire du Conseil d'Etat de France, membre du Conseil supérieur des Chemins de fer de France; 2, rue de Laplanche, Paris.

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General secretary: P. **Ghilain** (already named).

Assistant secretaries: A. W. **Chantrell**, ingénieur principal au Service du Matériel de la Société Nationale des Chemins de fer belges;

J. **Dubus**, ingénieur au Service de la Voie de la Société Nationale des Chemins de fer belges;

E. **Minsart**, ingénieur principal au Service du Matériel de la Société Nationale des Chemins de fer belges.

(1) Retires at the 14th session.

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(3) Retires at the 16th session